NASA'S AERONAUTICS R&D PROGRAM: STATUS AND ISSUES

HEARING

BEFORE THE

SUBCOMMITTEE ON SPACE AND AERONAUTICS

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

SECOND SESSION

MAY 1, 2008

Serial No. 110–99

Printed for the use of the Committee on Science and Technology

Available via the World Wide Web: http://www.science.house.gov

U.S. GOVERNMENT PRINTING OFFICE

41–902PS WASHINGTON : 2008

For sale by the Superintendent of Documents, U.S. Government Printing Office
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DEVIN BRYANT *Research Assistant*

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May 1, 2008

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NASA'S AERONAUTICS R&D PROGRAM: STATUS AND ISSUES

THURSDAY, MAY 1, 2008

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON SPACE AND AERONAUTICS,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:10 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Mark Udall [Chairman of the Subcommittee] presiding.

COMMITTEE ON SCIENCE AND TECHNOLOGY
SUBCOMMITTEE ON SPACE & AERONAUTICS
U.S. HOUSE OF REPRESENTATIVES
WASHINGTON, DC 20515

Hearing on

NASA's Aeronautics R&D Program: Status and Issues

May 1, 2008
10:00 a.m. – 12:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. Jaiwon Shin
Associate Administrator
Aeronautics Research Mission Directorate
NASA

Carl J. Meade
Co-Chair
Committee for the Assessment of NASA's Aeronautics Research Program
National Research Council

Preston A. Henne
Senior Vice President
Programs, Engineering and Test
Gulfstream Aerospace Corporation

Dr. Ilan Kroo
Professor
Department of Aeronautics and Astronautics
Stanford University

HEARING CHARTER

SUBCOMMITTEE ON SPACE AND AERONAUTICS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

NASA's Aeronautics R&D Program: Status and Issues

THURSDAY, MAY 1, 2008
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

Purpose

On Thursday, May 1, 2008 at 10:00 a.m., the House Committee on Science and Technology's Subcommittee on Space and Aeronautics will hold a hearing to review NASA's current Aeronautics R&D Program, examine what needs to be done to make it as relevant as possible to the Nation's needs, and in particular to examine R&D challenges related to safety and environmental impacts.

Witnesses

Witnesses scheduled to testify at the hearing include the following:

Dr. Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, National Aeronautics and Space Administration

Carl J. Meade, Co-Chair, Committee for the Assessment of NASA's Aeronautics Research Program, National Research Council, National Academies

Preston A. Henne, Senior Vice President, Programs, Engineering and Test, Gulfstream Aerospace Corporation

Dr. Ilan Kroo, Professor, Department of Aeronautics and Astronautics, Stanford University

Potential Issues

The following are some of the potential issues that might be raised at the hearing:

- Why is it important for the Federal Government to invest in aeronautics R&D, and is the current level of investment adequate?
- What needs to be done to ensure that NASA's aeronautics R&D is relevant to the Nation's needs and to maintain U.S. leadership?
- How can NASA's aeronautics R&D activities be more rapidly transitioned to the marketplace and to public sector users?
- How can NASA work most effectively with industry and the universities to carry out a meaningful aeronautics R&D program?
- What are the most important aviation safety issues facing the Nation, and what is NASA's aeronautics R&D program doing to address them?
- What are the most important issues related to aviation's impact on the environment, e.g., noise, emissions, and energy consumption, and what is NASA's aeronautics program doing to address them?
- What are the most important aeronautics R&D issues that will need to be addressed if the Next Generation Air Transportation System (NextGen) initiative is to succeed, and what is NASA's role in addressing them?
- What are the most promising flight regimes for NASA to investigate and what R&D initiatives would offer the most promise for such areas as supersonic flight, V/STOL flight, and so forth?
- What are the most important challenges to be addressed if the Nation is to sustain an efficient, environmentally compatible, and safe aviation system? What should NASA's role be in addressing those challenges and is NASA's current aeronautics R&D program able to fill that role?

BACKGROUND

Overview

NASA has long been a major source of the Nation's aeronautical research and development (R&D), R&D that has found application in both civil and military systems. However, funding for NASA's aeronautics program has been in decline for a major portion of the decade, in spite of recent congressional efforts to reverse that negative trend. In addition, beginning in late 2005, NASA began restructuring its aeronautics program to move away from a program that included technology demonstration projects and R&D that led to greater technology maturity towards a program focused on more fundamental research. These changes in NASA's Aeronautics R&D program occur at a time when the Next Generation Air Transportation System initiative known as NextGen is ramping up and increased concerns about aviation's actual and potential impact on the environment are growing.

NextGen is intended to transform the existing air traffic control system to accommodate projected growth in air passenger and cargo rates over the next decade. As part of this modernization, NextGen aims to develop a more efficient and more environmentally friendly national air transportation system, while maintaining safety. The development of NextGen is being overseen by the Joint Planning and Development Office (JPDO), a joint initiative of the Department of Transportation, NASA, Commerce, Defense Homeland Security, and the White House OSTP. FAA has traditionally relied on NASA for a significant portion of the R&D related to air traffic management as well as research to help address substantial noise, emissions, efficiency, performance, and safety challenges that are required to ensure vehicles can support the NextGen vision.

NASA's capabilities are likely to be needed even more in the years ahead as worldwide debate intensifies over how to deal with climate change caused by aviation. Aviation greenhouse gas emissions dominated the discussions last year at the ICAO Assembly in Montreal. And in late 2007, the European Union continued discussions on how to impose its emissions trading system on international aviation. R&D will be needed in several areas to meet the objectives of improving scientific understanding of the impacts of aviation; accelerating air traffic management improvements and efficiencies to reduce fuel burn; hastening the development of promising environmental improvements in aircraft technology; and exploring alternatives to current greenhouse gas (GHG)-emitting fuels for aviation.

Promising research is already being conducted by NASA in several of these areas, including collaborations with industry for research at the system level on projects such as the X–48B Blended Wing with Boeing, Geared Turbo Fan with Pratt & Whitney, and sonic boom suppression technologies with Gulfstream Aerospace. However, the declining funding for Aeronautics R&D in NASA's budgets provides a worrisome backdrop that calls into question the Agency's ability to meet the expectations of federal and private sector partners. The assessment of NASA's Aeronautics Research Program just completed by a Committee established by the National Research Council (NRC) reinforces concern over NASA's ability to successfully conduct a comprehensive aeronautics R&D program under the budgets given to NASA's aeronautics program.

Projecting what the air transportation system will look like and anticipating how to deal with increased demand, the integration of new aircraft technology in the National Airspace System, safety issues, and aviation's effect on the environment will require a responsive aeronautics R&D program at NASA. However, NASA's Aeronautics Research Program will be severely challenged in attempting to address those issues under current budgetary trends.

Fiscal Year 2009 Budget Request

NASA's FY09 budget provides $446.5 million for the Aeronautics Research Program under the direction of Aeronautics Research Mission Directorate (ARMD). It should be noted that NASA's FY 2009 budget has been restructured pursuant to the *Consolidated Appropriation Act,* 2008, and is now presented in seven accounts. In addition, the budget estimates presented in the FY 2009 request are in direct program dollars rather than in the full cost dollars used in previous Presidential budget requests. From a direct cost perspective,[1] the proposed FY09 budget for Aero-

[1] As part of the budget restructuring, NASA shifted from a full-cost budget, in which each project budget included overhead costs, to a direct cost budget. All overhead budget estimates are now consolidated into the Cross Agency Support budget line. NASA has stated that maintaining a full cost budget with seven appropriations accounts would be overly complex and inefficient. The direct cost budget shows program budget estimates that are based entirely on pro-

nautics Research is a decrease of $65.2 million from that appropriated in FY08. This continues a multi-year trend of declines in the budget requests for NASA's aeronautics programs.

The Aeronautics Research Program budget funds:

- Fundamental Aeronautics. The FY09 request for Fundamental Aeronautics is $235.4 million, a decrease of $34.5 million from the $269.9 million enacted in FY08. Long-term research conducted by the Fundamental Aeronautics Program will be used to provide feasible solutions to the performance and environmental challenges of future air vehicles. Research efforts in revolutionary configurations, lighter and stiffer materials, improved propulsion systems, and advanced concepts for high-lift and drag reduction all target the efficiency and environmental compatibility of future air vehicles. NASA's FY09 budget request says that space exploration activities will benefit from fundamental technology advances that can impact the Agency's future ability to both access space and survive the planetary entry, descent, and landing phase of missions to other planetary surfaces.
- Airspace Systems. The FY09 request for Airspace Systems is $74.6 million, a decrease of $25.5 million from the $100.1 million enacted in FY08. The Airspace Systems Program is intended to address the air traffic management research needs of NextGen in collaboration with the member agencies of the JPDO. NASA is working with the JPDO as well as other government, industry, and academic partners to enable the formation, development, integration, and demonstration of revolutionary concepts, capabilities, and technologies intended to allow significant increases in capacity, efficiency, and flexibility of the National Airspace System.
- Aviation Safety. The FY09 request for Aviation Safety is $62.6 million, a decrease of $3.9 million from the $66.5 million enacted in FY08. The program builds on NASA's unique safety-related research capabilities to improve aircraft safety for current and future aircraft, and to overcome aircraft safety technological barriers that would otherwise constrain the full realization of NextGen. To that end, NASA says that it is focusing its Aviation Safety Program on developing cutting-edge technologies to improve the intrinsic safety attributes of current and future aircraft that will operate in NextGen. For example, NASA's work on an Integrated Intelligent Flight Deck will include research into a forward looking sense-and avoid concept aimed at detecting hazardous icing conditions with ground-based and on-board sensing technologies, a potentially significant safety capability for the flying public. Furthermore, the Aviation Safety Program supports NASA's human and robotic exploration missions by advancing knowledge, tools, and technologies in areas relevant to operations in harsh environments.
- Aeronautics Test Program. The FY09 request for the Aeronautics Test Program is $73.9 million, a decrease of $1.2 million from the $75.1 million enacted in FY08. Prior to 2005, NASA's management approach for major test facilities was for each NASA Research Center to be fully responsible for their Center's facilities. NASA believed that this approach limited the potential ability to pursue Agency-wide approaches and hampered interaction. In 2006, the Aeronautics Test Program was developed to establish corporate management of NASA's aeronautics ground test facilities. This was done, NASA says in its FY09 budget request, to *optimize utilization of the Agency's wind tunnel and air breathing propulsion test facility assets for efficiency and cost effectiveness; to sustain and improve NASA's core capability of wind tunnel and air breathing propulsion testing; and to ensure a minimum core capability is maintained.*

NASA's out-year projections for the Aeronautics Research in the President's FY09 budget request show only minor changes in projected funding levels through 2013. As a point of comparison, NASA Aeronautics funding was about $1.85 billion (2006 dollars) in 1994—the current budget request is thus only about 24 percent of that level.

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gram content. Individual project managers continue to operate in a full-cost environment, including management of overhead costs.

$ in millions					
FY 2008 Enacted	FY2009 Request	FY 2010	FY2011	FY2012	FY2013
511.7	446.5	447.5	452.4	456.7	467.7

Congressional Direction to Develop a National Aeronautics R&D Policy and Plan

In the 2005 *NASA Authorization Act,* Congress reaffirmed the national commitment to aeronautics research made in the *National Aeronautics and Space Act of 1958* and went on to state that *"Aeronautics research and development remains a core mission of NASA. NASA is the lead agency for civil aeronautics research."* The Act also directed that the government of the United States *"promote aeronautics research and development that will expand the capacity, ensure the safety, and increase the efficiency of the Nation's air transportation system, promote the security of the Nation, protect the environment, and retain the leadership of the United States in global aviation."* The Act also directed the development of a national policy to guide the aeronautics research and development programs of the United States through 2020. The policy was to include national goals for aeronautics research and development and describe the role and responsibilities of each Federal agency that will carry out the policy.

In addition, the Act specified that the national aeronautics research and development policy describe for NASA (a) the priority areas of research for aeronautics through fiscal year 2011; (b) the basis on which and the process by which priorities for ensuing fiscal years will be selected; (c) the facilities and personnel needed to carry out the aeronautics program through fiscal year 2011; and (d) the budget assumptions on which the policy is based.

In developing the national aeronautics research and development policy, the Act specified consideration of several issues, namely:

- The extent to which NASA should focus on long-term, high-risk research or more incremental research, and the expected impact of that decision on the United States economy, and the ability to achieve environmental and other public goals related to aeronautics.
- The extent to which NASA should address military and commercial needs.
- How NASA will coordinate its aeronautics program with other federal agencies.
- The extent to which NASA will conduct research in-house, fund university research, and collaborate on industry research, and the expected impact of that mix of funding on the supply of United States workers for the aeronautics industry.

In response to the congressional direction, the Bush Administration released its National Aeronautics Research and Development Policy, along with its accompanying Executive Order 13419. That policy established principles and objectives to drive federal aeronautics R&D activities and guidelines that delineate agency roles and responsibilities in (a) stable and long-term foundational research; (b) advanced aircraft systems development; (c) air transportation management systems; and (d) national research, development, test and evaluation infrastructure. The Policy also called for an infrastructure plan for managing critical federal research, development, test and evaluation (RDT&E) assets.

The National Aeronautics R&D Policy laid out seven key principles to guide the conduct of the Nation's aeronautics R&D activities through 2020. These principles (with two exceptions discussed later) served as the framework for the R&D Plan issued in December 2007:

- Mobility through the air is vital to economic stability, growth, and security as a nation.
- Aviation is vital to national security and homeland defense.
- Aviation safety is paramount.

- Security of and within the aeronautics enterprise must be maintained.
- The United States should continue to possess, rely on, and develop its world-class aeronautics workforce.
- Assuring energy availability and efficiency is central to the growth of the aeronautics enterprise.
- The environment must be protected while sustaining growth in air transportation.

For each principle addressed in the plan, the state-of-the-art of related technologies and systems was provided as well as a set of fundamental challenges and associated high-priority R&D goals and supporting objectives for each goal. Objectives are phased over three time periods: near-term (<5 years), mid-term (5–10 years), and far-term (>10 years). Two principles in the Policy are being addressed in different efforts. Specifically, Aviation security R&D efforts are coordinated through the National Strategy for Aviation Security and its supporting plans. Aerospace workforce issues are being explored by the Aerospace Revitalization Task Force led by the Department of Labor.

The infrastructure plan called for in the 2005 Authorization Act has yet to be completed. The R&D Plan issued in December 2007 outlined future steps in developing the RDT&E infrastructure plan that will focus on the critical RDT&E assets and capabilities necessary to support the aeronautics R&D goals and objectives laid forth in this Plan. The RDT&E infrastructure includes experimental facilities and computational resources, as well as the cyber-infrastructure that serves to connect the two. The supplemental infrastructure plan will also address an approach for constructing, maintaining, modifying, or terminating assets based on the needs of the broad user community.

Establishing Research Priorities: NRC's Decadal Survey of Civil Aeronautics

In 2005, NASA contracted with the NRC to develop a consensus document representing the external (industry and academia) community's views about what NASA's aeronautics research priorities ought to be. The Decadal Survey of Civil Aeronautics was the first decadal survey ever produced for NASA's aeronautics program. Eighty-five aeronautics experts from academia, industry, and federal laboratories met and worked over a one-year period to develop a consensus document. The report laid out five key areas for research: aerodynamics and aeroacoustics; propulsion and power; materials and structures; dynamics, navigation and control, and avionics; and intelligent and autonomous systems, operations and decision-making, human integrated systems, networking and communications. Overall, the Decadal Survey laid out a prioritized list of 51 challenges to address and recommended that NASA use them as the foundation for its aeronautics program over the next decade.

The report was the subject of hearings before the House Committee on Science and Technology's Subcommittee on Space and Aeronautics in July and September of 2006. At the first of those hearings, then Subcommittee Chairman Ken Calvert raised concern over instability in NASA's aeronautics R&D program, saying that *"NASA's aeronautics program has, in recent years, been prone to changes in leadership and program goals and strategies."* At that same hearing, then Ranking Democratic Member Mark Udall called for investing in aeronautics R&D, thereby leading to such important efforts as enhancing the capability of America's air transportation system and enabling more environmentally compatible aircraft with significantly lower noise emissions and energy consumption relative to aircraft currently in service. He also warned that *"if we don't reverse this budgetary decline that NASA's aeronautics program is undergoing, we are not going to have the robust and vital R&D program we need and the [NRC] report envisions."*

NRC's Assessment of NASA's Aeronautics Research Program

The 2005 *NASA Authorization Act* directed the NASA Administrator to enter into an arrangement with the NRC for an assessment of the Nation's future requirements for fundamental aeronautics research and whether the Nation will have a skilled research workforce and research facilities commensurate with those requirements. The assessment was to include an identification of any projected gaps, and recommendations for what steps should be taken by the Federal Government to eliminate those gaps.

The Committee for the Assessment of NASA's Aeronautics Research Program found that *"even though the NASA aeronautics program has the technical ability to address each of the highest-priority R&T challenges from the Decadal Survey individually (through in-house research and/or partnerships with external research orga-*

nizations), ARMD would require a substantial budget increase to address all of the challenges in a thorough and comprehensive manner."

The Committee recommended that NASA:

- Ensure that *"its research program substantively advances the state of the art and makes a significant difference in a time frame of interest to users of the research results by (1) making a concerted effort to identify the potential users of ongoing research and how that research relates to those needs and (2) prioritizing potential research opportunities according to an accepted set of metrics. In addition, absent a substantial increase in funding and/or a substantial reduction in other constraints that NASA faces in conducting aeronautics research (such as facilities, workforce composition, and federal policies), NASA, in consultation with the aeronautics research community and others as appropriate, should redefine the scope and priorities within the aeronautics research program to be consistent with available resources and the priorities identified in (2), above (even if all 51 highest-priority R&T challenges from the Decadal Survey of Civil Aeronautics are not addressed simultaneously). This would improve the value of the research that the aeronautics program is able to perform, and it would make resources available to facilitate the development of new core competencies and unique capabilities that may be essential to the Nation and to the NASA aeronautics program of the future."*
- Bridge *"the gap between research and application—and thereby increase the likelihood that this research will be of value to the intended users."* Furthermore, the Committee recommended that NASA, for *"technology intended to enhance the competitiveness of U.S. industry, establish a more direct link between NASA and U.S. industry to provide for technology transfer in a way that does not necessarily include the immediate, public dissemination of results to potential foreign competitors."*
- Develop *"a vision describing the role of its research staff as well as a comprehensive, centralized strategic plan for workforce integration and implementation specific to ARMD. The plan should be based on an ARMD-wide survey of staffing requirements by skill level, coupled with an availability analysis of NASA civil servants available to support the NASA aeronautics program. The plan should identify specific gaps and the time frame in which they should be addressed NASA should reduce the impact of facility shortcomings by continuing to assess facilities and mothball or decommission facilities of lesser importance so that the most important facilities can be properly sustained."*

The Challenge of Sustaining an Efficient, Environmentally Compatible, and Safe Aviation System in the Face of Increasing Demand

As evidenced by frequent reports of flight delays around the country, the Nation's air transportation system is reaching saturation. The number of passengers using the system has been climbing steadily. In 2006, passengers exceeded 750 million; it is likely that between 2012 and 2015, the number of passengers could reach one billion each year. At that point, the air transportation system will be reaching its limits. Some models project that the number of passengers could double or even triple by the year 2025.

In the U.S., the major effort to develop a new air transportation system falls under the aegis of NextGen. The vision for NextGen is a system that is based on satellite navigation and control, digital non-voice communication and advanced networking. Furthermore, NextGen envisions shifting of decision-making from the ground to the cockpit. Flight crews will have increased control over their flight trajectories and ground controllers will become traffic flow managers. The air transportation system of the future will likely need to accommodate new flight regimes such as supersonic flight and the emergence of scheduled vertical and short take-off and landing (V/STOL) airline operations. Recent aircraft groundings for inspection of wiring bundles remind us that aviation safety issues associated with existing aircraft will also continue to need to be addressed.

There has long been a recognition of the need for R&D to minimize the adverse impacts on the environment, namely in the areas of aircraft noise around airports, energy consumption, and engine emissions. This is particularly important in light of the expected growth in air travel projected in the next decade. Some progress has been achieved in noise reduction for conventional fixed wing aircraft. FAA cites a decrease from seven million to half a million people exposed to significant aircraft noise in the past thirty years, this despite a significant number of passenger emplanements. Such a reduction was made possible through the evolution of aircraft powerplants, from the use of turbojets to more efficient and quieter generations of turbofans which have benefited from NASA R&D. However, noise remains a significant issue, particularly around the Nation's busiest airports and more needs to be done. Noise also has been a significant challenge for civil V/STOL aircraft.

Airlines and other users of the Nation's air transportation system are particularly sensitive to the cost of fuel, and R&D to increase aircraft energy efficiency has been a significant focus of NASA's aeronautics R&D program at various times. Yet technical or operational measures to promote energy efficiency have to be considered in the context of the overall aviation system. As a result, air transportation is particularly sensitive to requirements that may impact on fuel efficiency. For example, higher fuel consumption is oftentimes the result of having to design aircraft capable of meeting airport noise restrictions. For that reason, there is high interest in future powerplants that are both quiet *and* fuel efficient. NASA's Ultra-Efficient Engine Technology (UEET) program was a government-industry cooperative effort to develop improved engine technologies. NASA's Space Act Agreement with Pratt & Whitney on the Geared Turbo Fan is a more recent illustration of NASA's work on this challenging problem.

Concerns about climate change and the impact of the aviation sector on global warming have spurred a variety of efforts to cut aviation emissions in the U.S. and overseas. Studies have determined that airlines contribute worldwide up to three percent of greenhouse gas emissions. Governmental and private sector organizations have implemented efforts to reduce aviation-related emissions. In the U.S., the focus has been on continued development of NextGen and R&D on engines. While there is increasing understanding of the impact of carbon dioxide, the impacts from other emissions are less well known. The goal is to identify the harmful emissions, accurately measure their impact, and design appropriate technologies or procedures to mitigate or eliminate their effects. In Europe, the response has been more aggressive. To cut aviation emissions, the European Union (EU) has embarked on an emission trading scheme for its airline industry. This trading scheme may include U.S. airlines serving Europe and has generated controversy. U.S. airlines are reported to have said that forced participation in the European Union's carbon trading plan violates international treaties. The Air Transport Association, the trade group for U.S. carriers, is reported to have called the European's focus on aviation emissions "out of proportion" and has noted the U.S. industry's success with market driven approaches such as buying more fuel-efficient aircraft, reducing the weight of their planes, and investigating alternative fuels.

In October 2007, the International Civil Aviation Organization (ICAO), the United Nations body responsible for regulating the aviation industry, rejected airline participation in Europe's Climate Emissions Trading System. Instead, ICAO created a group of senior government officials to recommend what action the body should take on climate change. Calling for an "aggressive" plan of action from the new group, ICAO is reported to have said that the options to be considered include voluntary measures, technological advances in both aircraft and ground-based equipment, more efficient operational measures, improvements in air traffic management, positive economic incentives, and market-based measures to achieve reductions in emission of greenhouse gases.

The European Union is also focusing its aeronautics R&D on environmental effects. Under the aegis of its Seventh Framework Programme, the EU's main instrument for funding research over the period 2007 to 2013, the Union will be conducting research on developing technologies to reduce the environmental impact of aviation with the aim of halving the amount of carbon dioxide emitted by air transport, cutting specific emissions of nitrogen oxides by 80 percent and halving perceived noise. The research will address green engine technologies, alternative fuels, novel aircraft/engine configurations, intelligent low-weight structures, improved aerodynamic efficiency, airport operations and air traffic management as well as manufacturing and recycling processes. The "Clean Sky" Joint Technology Initiative will bring together European R&D stakeholders to develop 'green' air vehicle design, engines and systems aimed at minimizing the environmental impact of future air transport systems. This initiative establishes a Europe-wide partnership between industry, universities and research centers, with a total public/private funding of $1.6 billion.

Last year, to better understand governmental, industry, and international efforts to reduce aviation-related emissions, the House Science and Technology Committee and the House Transportation and Infrastructure Committee asked the Government Accountability Office to survey those various initiatives, their potential to reduce emissions, and the competitive impact on U.S. airlines. The Committees are awaiting GAO's report.

Analyzing Safety Trends—NAOMS and ASIAS

Last September, in a letter denying a press request under the Freedom of Information Act for the data generated through a survey of airline pilots about safety incidents conducted under the National Aviation Operations Monitoring Service (NAOMS), a NASA official indicated that the data would not be released because it is *"sensitive and safety-related, [and] could materially affect the public confidence in, and the commercial welfare of, the air carriers and general aviation companies whose pilots participated in the survey"*—a position subsequently reversed by the NASA Administrator. The survey was intended to be a forward-looking tool to identify emerging aviation safety problems. Instead, NASA had decided to stop the NAOMS project—despite the fact that the project had enjoyed unusual success in gathering responses from pilots.

NASA subsequently posted redacted responses collected from surveys of general aviation pilots and airline carrier pilots between April 2001 and December 2004 and a portion of the actual or raw survey responses collected to *"show the breadth and scope of the pilot community surveyed and the types of aircraft flown."* In February of this year, five Members of the Committee asked the Government Accountability Office to use the unredacted set of data collected by the NAOMS project to provide the Committee with an appropriate level of analysis of the data and verification of the survey methodology. The Committee is awaiting the results of GAO's analysis.

The value of having another tool to enhance safety, such as NAOMS, was demonstrated last week. It was reported that the Department of Transportation's Inspector General found that managers at a Texas facility had reclassified errors by controllers as mistakes by pilots. The errors included instances in which controllers allowed aircraft to get too close to one another and others in which pilots were given improper or late instructions. FAA officials noted that none of the errors resulted in crashes but provided no further details. While the report was not released, the FAA Acting Administrator characterized the report as "disturbing." The availability of corroborative data from another source, such as NAOMS, might have provided FAA with an earlier indication that the reclassifications were not warranted.

NASA currently is working with FAA and the Commercial Aviation Safety Team (a cooperative government-industry initiative) on the development of the Aviation Safety Information Analysis and Sharing (ASIAS) system. ASIAS is intended for use by the aviation community to automatically integrate and analyze large sources of operational flight data in order to detect and mitigate system-wide anomalies or dangerous trends before an accident occurs. If ASIAS works as planned, government and industry stakeholders will be able to query operational data to automatically identify systemic risks, evaluate identified risks, and formulate and monitor the effectiveness of safety interventions targeted at identified risks. However, achieving such capabilities will not be easy. In addition to the challenge of developing and delivering new algorithms to automatically detect and identify vulnerabilities, NASA and its partners will need to develop new methods to automatically integrate and process large sources of disparate data.

Chairman UDALL. Good morning. I would like to welcome our witnesses to today's hearing, and thank you for your participation.

Today the Subcommittee continues our oversight of NASA's major programs by focusing on aeronautics. It is important that we do so because in many ways, NASA's aeronautics program is one important answer to the question of what it is that makes NASA relevant to the Nation's needs.

At the same time, it has become painfully clear that NASA's aeronautics program has been significantly shortchanged in recent years when it comes to getting the resources required to address those national needs. That is unacceptable as far as I am concerned. NASA has many worthwhile programs underway, activities that certainly deserve our support. Yet I am hard-pressed to think of any program at NASA, with the possible exception of NASA's climate research initiatives, that is more relevant to our society's needs than NASA's aeronautics program.

Aviation knits our country together, maintains our economic vitality, improves the quality of our lives and helps enhance our national security. Moreover, aviation is a sector that makes a significant positive contribution to our balance of our trade and promotes America's competitiveness in the global economy.

Yet the explosive growth of aviation over the last several decades has brought its own set of challenges. These include dealing with the increasing congestion of the Nation's airspace system, the need to maintain safety in the face of increasing travel demand and the need to mitigate the negative impacts of aviation on the environment, whether noise, increasing energy consumption or harmful emissions.

Now, with respect to emissions, it is clear that an emerging focus of concern is greenhouse gas emissions that can contribute to climate change, an area that this committee has been trying to call attention to over the past year. It is clear that meeting all those challenges is going to require a national commitment to cutting-edge research into new technologies and operational procedures.

We must focus on research that will ensure that the Nation's air traffic management system will be able to meet anticipated demand while preserving safety and making the whole experience a lot more pleasant than it is now for the average traveler. We also need to focus on developing technologies that make aircraft much more energy efficient and produce lower levels of harmful emissions.

In addition, NASA needs to continue to pursue research that will open up new flight regimes for our utilization, for example, research that will enable such things as civil rotorcraft and supersonic aircraft that are environmentally friendly, safe and that can operate without adverse impacts on our communities. We need to focus on research that will ensure that we maintain the high level of safety that we have enjoyed in our aviation sector.

Indeed, the National Academies completed a Decadal Survey of Civil Aeronautics several years ago that identified some 51 key technical challenges around which NASA, in close collaboration with industry and academia, could structure a compelling and productive aeronautics R&D agenda for the next decade. That is the good news.

However, as a number of witnesses at today's hearing will testify, and as past witnesses have also testified, the decline in NASA's aeronautics funding is making it increasingly difficult to maintain an aeronautics research program that will be capable of stepping up to the challenges the Nation's aviation sector will be facing in the coming decades.

In short, the future relevance of NASA's aeronautics program is at risk, just when the need for NASA'S research contributions is greatest. In part, that is because carrying research to a level of maturity that allows the results to be transitioned to the users, whether in the public or the private sector, requires a greater level of investment than the current Administration has been willing to make. That needs to change. If promising technologies and operational concepts aren't matured to the point that they can be transitioned to the users for future development or implementation, the Nation will never receive the full benefit of the investment that is made in that research. That is the challenge we face.

Aeronautics needs to be a priority at NASA. It is as simple as that. I think the *NASA Reauthorization Act of 2005* got it right when it reaffirmed that "Aeronautics research remains a core mission of NASA."

Our witnesses today will tell us about the ways that NASA research can contribute to a bright and exciting future for American aviation. We need to ensure that NASA maintains its commitment to carrying out that research, and we have a lot to discuss at today's hearing so at this point I will again thank our witnesses for your participation, and we very much look forward to your testimony.

[The prepared statement of Chairman Udall follows:]

PREPARED STATEMENT OF CHAIRMAN MARK UDALL

Good morning. I'd like to welcome our witnesses to today's hearing and thank you for your participation.

Today, the Subcommittee continues our oversight of NASA's major programs by focusing on Aeronautics.

It is important that we do so, because in many ways NASA's aeronautics program is one important answer to the question of what it is that makes NASA relevant to the Nation's needs.

At the same time, it has become painfully clear that NASA's aeronautics program has been significantly shortchanged in recent years when it comes to getting the resources required to address those national needs.

That's unacceptable as far as I am concerned. NASA has many worthwhile programs underway—activities that certainly deserve our support.

Yet I am hard-pressed to think of any program at NASA, with the possible exception of NASA's climate research initiatives, that is more relevant to our society's needs than NASA's aeronautics program.

Aviation knits our country together, maintains our economic vitality, improves the quality of our lives, and helps enhance our national security.

Moreover, aviation is a sector that makes a significant positive contribution to our balance of trade—and promotes America's competitiveness in the global economy.

Yet the explosive growth of aviation over the last several decades has also brought its own set of challenges.

These include dealing with the increasing congestion of the Nation's airspace system, the need to maintain safety in the face of increasing travel demand, and the need to mitigate the negative impacts of aviation on the environment—whether noise, increasing energy consumption, or harmful emissions.

And with respect to emissions, it is clear that an emerging focus of concern is greenhouse gas emissions that can contribute to climate change, an area that this committee has been trying to call attention to over the past year.

It is clear that meeting all of those challenges is going to require a national commitment to cutting-edge research into new technologies and operational procedures.

We must focus on research that will ensure that the Nation's air traffic management system will be able to meet anticipated demand while preserving safety and making the whole experience a lot more pleasant than it is now for the average traveler.

We also need to focus on developing technologies that can make aircraft much more energy efficient and produce lower levels of harmful emissions.

In addition, NASA needs to continue to pursue research that will open up new flight regimes for our utilization, for example, research that will enable such things as civil rotorcraft and supersonic aircraft that are environmentally friendly, safe, and that can operate without adverse impacts on our communities.

And we need to focus on research that will ensure that we maintain the high level of safety that we have enjoyed in our aviation sector.

Indeed, the National Academies completed a Decadal Survey of Civil Aeronautics several years ago that identified some 51 key technical challenges around which NASA—in close collaboration with industry and academia—could structure a compelling and productive aeronautics R&D agenda for the next decade.

That's the good news.

However, as a number of the witnesses at today's hearing will testify, and as past witnesses have also testified—the decline in NASA's aeronautics funding is making it increasingly difficult to maintain an aeronautics research program that will be capable of stepping up to the challenges the Nation's aviation sector will be facing in the coming decades.

In short, the future relevance of NASA's aeronautics program is at risk—just when the need for NASA's research contributions is greatest.

In part that is because carrying research to a level of maturity that allows the results to be transitioned to the users—whether private or public sector—requires a greater level of investment than the current Administration has been willing to make.

That needs to change.

If promising technologies and operational concepts aren't matured to the point that they can be transitioned to the users for further development or implementation, the Nation will never receive the full benefit of the investment that it has made in that research.

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We need to ensure that NASA maintains its commitment to carrying out that research.

We have much to discuss at today's hearing, so at this point I will again thank our witnesses for your participation, and we look forward to your testimony.

Chairman UDALL. It is with great pleasure I now recognize the Ranking Member, my partner, Mr. Feeney, for an opening statement.

Mr. FEENEY. Thank you, Chairman Udall, for calling today's hearing and thanks also to our witnesses for taking time away from their busy schedules to come before us today. I realize most of you have traveled some distance, carving at least a day, if not two, out of your week to be here with us and I appreciate that. Your wisdom and expertise are greatly appreciated.

Mr. Chairman, there are very few enterprises over the past 100 years that have contributed so powerfully to America's economy and enhanced our nation's quality of life and our security than NASA's aeronautics research and development program. It actually began some 93 years ago with the establishment of the National Advisory Committee for Aeronautics in 1915. Even though the Wright Brothers had conducted their first powered flight in 1903, by the beginning of World War I, the United States lagged behind

Europe in airplane technology. In order to catch up, Congress founded NACA.

NACA involved into a splendid organization that produced gems of aeronautical research. In 1958, NACA was folded into NASA when the latter was created in response to the Sputnik mission. Exemplary aeronautical research continued. And the Space Task Force, which drew from the talented base at NACA's Langley Memorial Aeronautical Laboratory, began America's human space flight program, Project Mercury.

The discoveries and applications that have flowed from NACA and NASA have spurred a large and vibrant aerospace industry. As should be expected, this industry and aerospace technology has evolved over time, especially over the last three decades. Since the late 1970s, the airline industry has been deregulated. Manufacturers and carriers have been consolidated. The airspace has become saturated. Building new runways and airports has become very difficult and very expensive. The size and performance of aircraft operating in the system are much more diverse and environmental performance and efficiency are driving designs of the next generation of aircraft. The list of changes goes on.

In the face of these changes, it is fair to ask how healthy and relevant is NASA's aeronautics program today. Is it appropriate for the Federal Government to continue to fund aeronautics research, and if so, where should the line be drawn between government and industry research responsibilities? Are NASA's aeronautics researchers pursuing the right questions? Is the Agency making the most effective use of research funding? Are the Agency's discoveries and products being adopted by industry?

Adding further complexity to the discussion is the NextGen program, of which NASA is a critical partner. Unlike the mixed results from past efforts to modernize the air traffic control system, NextGen must succeed. There is no alternative. In the increasingly competitive global economy, America's advantages in mobility and logistics cannot be frittered away.

And in an era of increased emphasis on energy and environmental concerns, I gently point out that NextGen's efficiencies will produce energy savings and a lessened environmental footprint as aircraft use more direct routes, experience less air and ground holds and employ techniques like Continuous Descent Approach. Improved mobility is environmentally friendly and economically beneficial.

But if NextGen is to succeed, NASA must develop and validate technologies to enable more efficient, environmentally benign and safer aircraft and engines as well as surveillance, navigation and control infrastructure.

I am hoping the testimony we will receive this morning will help us reach a broad consensus on how to shape the program to meet current and future challenges. I am especially anxious to hear the views of industry and from the National Research Council about their findings and recommendations contained in their recently published analysis of NASA's aeronautics programs. I also want to congratulate Dr. Shin, a longtime NASA aeronautics researcher, who was recently appointed to head the Agency's aeronautics directorate.

Aeronautics is not a mature industry. Any number of new technologies that enable cleaner, quieter, more efficient aircraft will make a telling difference between success and failure. We cannot afford to cede our leadership to foreign suppliers.

With that, Mr. Chairman, again thank you for the hearing and I look forward to hearing from our witnesses.

[The prepared statement of Mr. Feeney follows:]

PREPARED STATEMENT OF REPRESENTATIVE TOM FEENEY

Thank you, Mr. Chairman, for calling this morning's hearing. And my thanks, too, to our witnesses for taking time away from their busy schedules to appear before us today. I realize most of you have traveled some distance, carving at least a day—if not two—out of your work week to be here. Your wisdom and expertise are greatly appreciated.

Mr. Chairman, there are very few federal enterprises over the past one hundred years that have contributed so powerfully to America's economy and enhanced our nation's quality of life—and our security—than NASA's aeronautics research and development program. It began 93 years ago with the establishment of the National Advisory Committee for Aeronautics (NACA) in 1915. Even though the Wright brothers conducted the first powered flight in 1903, by the beginning of World War I, the United States lagged behind Europe in airplane technology. In order to catch up, Congress founded NACA.

NACA evolved into a splendid organization that produced gems of aeronautical research. In 1958, NACA was folded into NASA when the latter was created in response to Sputnik. Exemplary aeronautical research continued. And the Space Task Force, which drew from the talent based at NACA's Langley Memorial Aeronautical Laboratory, began America's human space flight program—Project Mercury.

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Adding further complexity to the debate is the NextGen program, of which NASA is a critical partner. Unlike the mixed results from past efforts to modernize the air traffic control system, NextGen must succeed. In the increasingly competitive global economy, America's advantages in mobility and logistics cannot be frittered away.

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Aeronautics is not a mature industry. Any number of new technologies that enable cleaner, quieter, more fuel efficient aircraft will make a telling difference between success and failure. We cannot afford to cede our leadership to foreign suppliers.

Thank you.

Chairman UDALL. Thank you, Mr. Feeney.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Thank you, Mr. Chairman for calling this hearing on NASA's Aeronautics R&D programs. As Chairman of the Aviation Subcommittee, I am extremely interested in these programs because NASA and FAA coordinate research for implementation of NextGen. Further, these programs also lead to further reductions in aviation's environmental impact. Our Aviation Subcommittee is having a hearing on aviation and the environment next week where we will delve further into aviation's environmental impacts, but I want to be clear that aeronautics R&D is a significant component in assisting the industry in its efforts to reduce aviation emissions.

A strong aerospace industry will enable the United States to defend itself, compete in the global marketplace, maintain a highly skilled workforce, and provide all Americans with the ability to travel safely and securely anywhere in the world. Continued reductions in the NASA aeronautics budgets delay our ability to meet the goals of NextGen, which is expected to reduce congestion and delays in our skies and produce great efficiencies in our aviation system.

I continue to be troubled that the Bush Administration sees NextGen as the answers to our congestion in the skies, but does not budget accordingly to reach that goal. R&D is essential to advancing NextGen and we cannot lose sight of that.

I welcome our witnesses and look forward to their testimony.

Chairman UDALL. I would like to move right to an introduction of our panel of witnesses. First up, we have Dr. Jaiwon Shin, who is the new Associate Administrator at NASA for the Aeronautics Research Mission Directorate. Congratulations on your new appointment. Next to Dr. Shin, we have Mr. Carl Meade, who is appearing today as the Co-Chair of the National Research Council's Committee for the Assessment of NASA's Aeronautics Research Program. Welcome to you. Mr. Preston Henne is the Senior Vice President for Programs, Engineering and Testing for Gulfstream Aerospace Corporation. We are looking forward to your testimony. There are some exciting things going on at Gulfstream. And then finally we have Dr. Ilan Kroo, who is Professor in the Department of Aeronautics and Astronautics at Stanford University. Welcome.

I think you all know that spoken testimony is limited to five minutes each, after which the Members of the Subcommittee will have five minutes each to ask questions. Dr. Shin, we will start with you.

STATEMENT OF DR. JAIWON SHIN, ASSOCIATE ADMINISTRATOR, AERONAUTICS RESEARCH MISSION DIRECTORATE, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)

Dr. SHIN. Chairman Udall, Ranking Member Feeney, thank you for this opportunity to appear before you today to provide an update on NASA's aeronautics research program. I will also address the issues raised by the Subcommittee concerning the R&D challenges in aeronautics, specifically the Next Generation Air Transportation System, or NextGen, aviation safety, aviation environmental impacts and promising new flight regimes.

As you know, NASA has a long and successful history of conducting R&D in technologies that have benefited our nation's aviation community. One such example is the vertical extensions found on wingtips, which help to improve an aircraft's full efficiency and cruising range, known as winglets——

Chairman UDALL. Dr. Shin, would you pull the microphone a little closer? We just want to make sure we get your words in the record. Thank you.

Dr. SHIN. Known as winglets, this technology was developed by NASA during the 1970s and is now found on aircraft of all types around the world. You should have before you a folder that depicts some examples of NASA innovation that have made a difference in the way we safely travel today. NASA's Aeronautics Research Mission Directorate, or ARMD, continues this tradition through its commitment to conducting long-term cutting-edge research for the benefit of the broad aeronautics community and in support of NASA's goals for both manned and robotic space exploration.

I believe that aviation in the United States could be on the verge of another renaissance. Demand for air travel is expected to double or even triple in the next two decades, which will require a revolutionary air transportation system. In order to realize this new system, a number of significant challenges must be overcome such as protecting the environment, ensuring safety, dramatically improving efficiency and revolutionizing the ways we manage the flow of aircraft. The aeronautics research that we conduct today will play a vital role in transforming the air transportation system of tomorrow.

While each of the four programs within ARMD uniquely address critical challenges, the four programs integrate their research for a holistic approach to high-level challenges such as NextGen. I would like to illustrate why this holistic approach is important by going over the four questions raised by the Committee.

As for the NextGen R&D issues, I must say that it is difficult to identify the most critical barrier to NextGen. While it is easy to consider the air traffic management system to be the most critical issue, the reality is, we must treat the entire system as an inter-related enterprise instead of segregating research into separate areas. To foster this thinking, ARMD's research programs address issues of air traffic management, avionics advanced vehicles, safety and environmental impact. The vast majority of what ARMD does is directly in line with the NextGen vision that is clearly supported by national aeronautics R&D policy.

It is a well-known fact that the current U.S. air transportation system is among the safest modes of transportation ever. Even as we dramatically transform our air transportation system, it is imperative that we maintain or preferably improve on this impressive safety record. ARMD's Aviation Safety Program is working on development of new technologies such as new airborne sensors of flight hazards, methods of controlling aircraft even in upset conditions and systems capable of monitoring aircraft and airspace to detect anomalies before they can develop into accidents. Likewise, the Aviation Safety Program is developing new materials and structures that can age with great durability and less fatigue and is establishing a research program in human system integration and NextGen operations.

I should point out that as the number of flight operations at many of the largest airports in the Nation continues to grow, environmental concerns over noise and emissions will limit the capacity of those airports and therefore limit the capacity of the entire system. NASA's Fundamental Aeronautics Program is working to improve the environmental impact of aviation through green aircraft research initiatives to reduce noise, local and global emissions and local air quality. We are also working on advanced vehicle concepts that will satisfy both forecasted demand and environmental compliance. Furthermore, the Aviation Systems Program is ensuring that today's fleet and new generations of vehicles can operate within the NextGen in a matter minimizing aviation's environmental impact.

NASA is not fixated on developing new capability in just one flight regime, and I believe that an ideal situation will exist when multiple vehicle types exist, each suited for a particular use, operating in an air transportation system that is flexible enough to accommodate a wide range of vehicles without limiting performance. Examples of some of the most promising concepts include advanced subsonic transonic transport with nearly half the fuel burn of today's vehicles and a noise footprint that can be confined to the boundary of the airport, advanced supersonic transports with low sonic boom characteristics so that the aircraft may be flown supersonically over land and advanced rotorcraft that allow vertical or short takeoff and landing with vastly improved range and performance and reduced environmental impact, mainly from noise.

I am pleased to report to you that NASA aeronautics now is in full execution of a robust fundamental research program that is well aligned with the national aeronautics R&D policy and directly supports the development of the NextGen system. ARMD's commitment to technical excellent with strong partnerships with industry, academia and other government agencies will ensure our reputation as the world's premier aeronautics R&D organization.

I welcome any questions you may have. Thank you.

[The prepared statement of Dr. Shin follows:]

PREPARED STATEMENT OF REPRESENTATIVE JAIWON SHIN

Chairman Udall and Members of the Subcommittee, thank you for this opportunity to appear before you today to provide an update on NASA's aeronautics research program and to address the issues raised by the Subcommittee concerning the R&D challenges in aeronautics; specifically, the Next Generation Air Transportation System (NextGen), promising new flight regimes, aviation safety, and aviation environmental impacts.

NASA has a long and successful history of conducting research and development (R&D) in technologies that have benefited our nation's aviation community. Today, NASA's Aeronautics Research Mission Directorate (ARMD) continues this tradition through its commitment to conducting long-term, cutting-edge research for the benefit of the broad aeronautics community. ARMD has put together a robust research portfolio that addresses the challenges facing our nation as it transforms its air transportation system to meet growing capacity needs. Furthermore, the portfolio ensures aeronautics research and critical core competencies continue to play a vital role in support of NASA's goals for both manned and robotic space exploration.

Growth in the air transportation system is vital to the well being of our nation. In order to realize the revolutionary changes required to meet forecasted capacity increases, a number of significant challenges must be overcome such as protecting the environment, ensuring safety, dramatically improving efficiency and revolutionizing the ways we manage the flow of aircraft. In the next two decades we must find ways to make advances that improve aircraft and system efficiency, reduce aviation's impact on the environment and allow more people to utilize air travel in ways that are more significant than all the gains realized over the last three decades. The research ARMD conducts today to address these issues will play a vital role in transforming the air transportation system of tomorrow.

ARMD Principles

Every successful organization can point to core principles that guide its strategic direction. Since the restructuring of NASA's aeronautics program in 2006, ARMD has been guided by three such core principles: 1) we will dedicate ourselves to the mastery and intellectual stewardship of the core competencies of aeronautics for the Nation in all flight regimes; 2) we will focus our research in areas that are appropriate to NASA's unique capabilities; and, 3) we will directly address the fundamental research needs of the NextGen while working closely with our agency partners in the Joint Planning and Development Office (JPDO). While the leadership of ARMD has changed, these principles remain core to our strategic decision-making process and help to guide the direction of all of our programs. These principles ensure that NASA is focused on the most appropriate cutting-edge research to overcome a wide range of aeronautics challenges facing our nation's future air transportation system and space exploration missions. Lastly, these principles have helped ARMD structure a robust aeronautics program that is well aligned with the principles, goals and objectives of the recent National Aeronautics R&D Policy and Plan.

Program Descriptions

Four programs have been established under ARMD using our guiding principles: the Fundamental Aeronautics Program, the Aviation Safety Program, the Airspace Systems. Program and the Aeronautics Test Program. While each program uniquely addresses critical challenges, the four programs integrate their research for a holistic approach to high level challenges such as NextGen. The following are brief descriptions of each program and how their research supports the broad aeronautic community.

ARMD's Fundamental Aeronautics Program (FAP) pursues long-term, cutting-edge research in all flight regimes (from subsonic to hypersonic) to produce data, knowledge FAP, and design tools that will be applicable across a broad range of air vehicles. FAT focuses on creating innovative solutions for the technical challenges of the future which include 1) increasing performance (including fuel efficiency, range, speed, payload, take-off and landing distances) while meeting stringent noise and emissions constraints; 2) alleviating environmental and congestion/capacity problems through the use of new aircraft and rotorcraft concepts; 3) improving the speed of air transportation while maintaining strict standards for performance and environmental compatibility; and 4) facilitating access to space and re-entry through planetary atmospheres. FAP research will directly support the NextGen challenges of overcoming the environmental and performance barriers to projected increases in capacity. Research in new aircraft and rotorcraft concepts will also directly support NextGen goals of better utilization of the airspace.

ARMD's Aviation Safety Program (AvSP) builds upon NASA's unique research capabilities to improve aircraft safety, and to overcome safety limits that would otherwise constrain the full realization of the NextGen system. To meet these safety challenges, AvSP focuses on developing cutting-edge technologies to improve the intrinsic safety attributes of current and future aircraft and also on exploring how NextGen operations can improve upon the existing remarkable safety record of our current air transportation system. Examples of new technologies with direct application to NextGen include new sensors and methods to automatically detect and identify flight hazards, hidden anomalies or trends in aircraft systems, advanced materials, and flight control systems resilient in the face of failure and adverse flight conditions such as weather.

ARMD's Airspace Systems Program (ASP) enables the development of revolutionary improvements to the national airspace system that allow sufficient capacity to meet increasing demand for air travel. ASP focuses on research to incorporate intelligent automation into the system with balanced roles for people and computers while preserving the high safety standard. Included in this is the development of automated aircraft trajectories that are safe, efficient and robust under a wide variety of traffic conditions. Solutions for enabling greater capacity at the busiest airports and in dense airspace integrate uncertainties, such as weather, into air traffic management decisions. The end result of ASP research is more efficient operations and reduced flight delays.

ARMD's Aeronautics Test Program (ATP) focuses on the support of both ground based facilities, such as wind tunnels and aero-propulsion test facilities, as well as the aircraft and flight test infrastructure. ATP makes strategic utilization, operations, maintenance, and investment decisions for major wind tunnels/ground test facilities at Ames Research Center in California, Glenn Research Center in Ohio, and Langley Research Center in Virginia, and supports selected mission support and test bed aircraft at Dryden Flight Research Center, also in California. ATP ensures the availability of world-class aeronautics test facilities and test aircraft for the benefit of the aeronautics community.

Addressing NextGen R&D Issues

Aviation in the United States is facing an exciting possibility for being on the verge of another renaissance. Demand for air travel is expected to double or even triple in the next two decades, which will require a revolutionary new air traffic management system. New technologies and design capabilities are making it possible to create entirely new vehicles that look radically different from the familiar "tube-and-wing" aircraft that are now so familiar. These new aircraft will bring remarkable new capabilities that may require entirely new operational procedures in the airspace. Aeronautics research is crucial to overcoming the numerous challenges that impede the growth of air travel. In addition, there is an inherent challenge of improving safety even as we increase capacity. NASA is focused on addressing these critical long-term challenges.

It is difficult to identify the "most critical" barrier to NextGen. Thus, one clear focus for NASA is treating the entire system as an inter-related enterprise, mirroring the National Aeronautics R&D Policy, instead of segregating research into separate areas. Alignment with the National Aeronautics R&D Policy helps ensure that NASA is focused on the most important R&D issues.

NASA understands that the NextGen concept involves much more than just revolutionizing the air traffic management system; it also includes the advanced aircraft concepts that will populate the system over the next several decades. In particular, NASA is focusing on three generations of vehicles beyond the current generation, "N," represented by the Boeing 787 for the fixed wing subsonic class of aircraft. Generation "N+1" is presumed to enter into service in 2015, market permitting, and is envisioned to be a tube-and-wing configuration but equipped with more advanced technologies than Generation "N" aircraft. Generation "N+2" will employ revolutionary concepts to achieve simultaneous gains in fuel burn, noise, and emissions, with an Initial Operating Concept around 2020. Generation "N+3" will follow with much improved performance and reduced environmental impact.

We must ensure that the airspace in which these aircraft will operate allows them to make full use of their capabilities. Simultaneously, we must also ensure that safety is not compromised. Our system-wide view of the entire air transportation system is reflected in the recent cross-Program NASA Research Announcement (NRA) topic entitled: "Integration of Advanced Concepts and Vehicles into the Next Generation Air Transportation System."

To foster this thinking, ARMD's three research programs address issues of Air Traffic Management (ATM), avionics, advanced vehicles, safety, and environmental impact. The vast majority of what ARMD does is directly aligned with the NextGen vision that is clearly supported by the National Aeronautics R&D Policy. The following examples illustrate the alignment of ARMD programs with the National Aeronautics R&D Policy and the NextGen vision:

- The Airspace Systems Program directly addresses the Policy's first principle of "mobility through the air" by conducting air traffic management research that will develop concepts, capabilities, and technologies required to meet the Nation's anticipated growth in airspace operations, both in the air and on the ground. The Fundamental Aeronautics Program directly addresses this principle by conducting research that can enable the development of advanced aircraft systems that fly with higher performance, lower fuel consumption, and minimum environmental impact (noise and emissions) at a range of speeds and from a wide variety of airports.
- The core mission of the Aviation Safety Program directly addresses the Policy's third principle that states that aviation safety is paramount.
- The Fundamental Aeronautics Program simultaneously addresses the Policy's sixth principle of "assuring energy availability and efficiency" and seventh principle of "protecting the environment" by conducting research to improve aircraft performance, increase fuel efficiency, evaluate alternative fuels, lower emissions (including particulate matter) and reduce noise. In addition, the Airspace Systems Program also addresses these two principles by conducting research to improve efficiency and reduce environmental impact through better utilization of the airspace.

Additional examples of specific challenges and the NASA strategy to address them are provided in the following sections.

Safety Issues Facing the Nation

The current U.S. air transportation system is among the safest modes of transportation ever. Throughout the implementation of NextGen it is imperative that we maintain or preferably improve on this impressive safety record. However, there is no single safety issue upon which to focus our efforts. Instead, we need to continually analyze for and predict safety issues as NextGen is implemented.

We do know that there are many complex aspects of NextGen that present research challenges accepted by all ARMD research programs. For example, a major challenge will be the proper design, integration, and use of automation in both ground-based and airborne systems. Meeting this challenge will require advances in human-machine integration capabilities, better decision-making through data and knowledge mining systems, and intelligent systems that adapt to failures and hazardous flight conditions. Another challenge is the need for improved software verification and validation techniques to prevent against anomalies that could propagate across highly integrated systems with unintended consequences. In addition, new aircraft create challenges for effective maintenance and continued airworthiness assurance of advanced materials and lightweight structures when exposed to typical operational hazards and aging effects.

Consequently, NASA's Aviation Safety Program conducts fundamental research across its four project areas to address both established and emerging safety barriers to the full realization of NextGen. For example, one aspect of the research portfolio is investigating human-machine integration issues to include the best use of automation. We also know that a myriad of new aircraft materials will be used, so NASA is working to predict the long-term aging effects to understand the fundamental characteristics of advanced materials and aircraft structures, with the intent to design and mitigate against aging related hazards. NASA is also looking at mitigating unknown issues that may develop iii flight by designing intelligent on-board systems that can respond to and reliably mitigate against failures and flight in adverse conditions such as icing. Finally, NASA is also researching new data mining techniques to predict future failures from trends in current operations. This involves a fundamental shift away from a forensic approach of trying to understand why an accident occurred to a prognostic approach to safety that allows unsafe conditions to be identified before they become tragic. NASA continues to work with the Commercial Aviation Safety Team and other stakeholders to identify current and emerging aviation safety issues.

The Impact of Aviation on the Environment

As NextGen evolves to meet the projected growth in demand for air transportation, NASA's Fundamental Aeronautics Program is working to answer two major questions: (1) how will we continue to reduce the environmental impact of aviation (in terms of noise, local and global emissions, and local air quality) despite growth? and, (2) what kinds of advanced vehicles will be required to satisfy both forecasted demand and environmental compliance? Furthermore, the Airspace Systems Program is ensuring that today's fleet and new generations of vehicles can operate within the NextGen in a manner minimizing aviation's environmental impact. These efforts represent significant investments in "green" aircraft research initiatives being led by NASA ARMD.

As the number of flight operations at many of the largest airports in the Nation continues to increase, environmental concerns over noise and emissions will limit the capacity of those airports, and therefore limit the capacity of the entire system. Concerns over global emissions (mostly over greenhouse gases) may radically change air transportation as we know it: without new and innovative aircraft concepts and air traffic management concepts that can provide unprecedented levels of performance and environmental compliance, the overall capacity of the system will be significantly hampered. By 2025, the demand for air transportation will be satisfied by a variety of classes of aircraft. The Fundamental Aeronautics Program is developing "green" ideas, technologies, and tools to enable the development of highly efficient and environmentally friendly aircraft (including subsonic aircraft; supersonic aircraft; and aircraft with the ability to take-off and land on short runways, yet cruise efficiently at transonic speeds) and rotorcraft to meet the performance and environmental requirements that will be demanded by the public. Below are some specific examples of NASA's ongoing work to mitigate the environmental (and global climate) impact of aviation:

1. NASA has set aggressive goals for fuel burn, noise, and emissions reductions for three generations of vehicles (referred to as "N+1, "N+2," and "N+3") and is pursuing technologies that can achieve each of these goals.

2. Advancement of hybrid wing-body vehicle ("N+2") technologies for low noise, higher performance, and better engine/airframe integration. These efforts have the potential of enabling aircraft that, unlike conventional tube-and-wing aircraft, can simultaneously achieve significantly reduced noise, emissions, and fuel burn.
3. System-level understanding of laminar flow control techniques for application in "N+1" and "N+2" concepts. Laminar flow technology can significantly decrease the fuel burn of both conventional and unconventional aircraft and, therefore accomplish significant CO_2 emissions reductions (up to 50 percent better than the current state-of-the-art).
4. Aggressive weight reduction technologies using advanced materials and structural concepts for both aircraft and engine structures with significant reduction of CO_2 emissions due to decreases in fuel burn.
5. Studies into the necessary technologies and integration approaches to realize significantly improved gas turbine engines with higher efficiency (resulting in lower CO_2 emissions) and lower NO_X emissions.
6. Efforts to assess the validity and applicability of biofuels/alternative fuels of various different sources to aviation applications.
7. Approaches to improve the viability of both supersonic transports and advanced rotorcraft in the NextGen incorporating environmental constraints.

In addition, NASA has recently issued a solicitation for the "N+3" generation of advanced vehicles (see *http://www.aeronautics.nasa.gov/fap*) that will have dramatically improved environmental performance to the point that emissions of CO_2 will be reduced by up to 70 percent and the noise of such aircraft will be barely noticeable outside airport boundaries.

To facilitate the transition of advanced ideas and technologies into the aircraft fleet, NASA is partnering with the Federal Aviation Administration's (FAA) Continuous Low Emissions, Energy and Noise (CLEEN) program to guide efforts to mature technologies that have already shown promise to the point where they can be adopted by the current and future aircraft fleet. This collaboration with the FAA is only one of the many joint activities that both agencies are pursuing to ensure that the environmental impact of aviation is significantly reduced in the presence of net growth.

Finally, NASA actively participates in Aviation Climate Change Research Initiative (ACCRI) to better understand and assess the global climate impact of current and future advanced vehicles. In fact, the "N+3" solicitation is specifically addressing some of the leading issues in global climate.

It is widely recognized that 90–95 percent of the environmental gains in the current air transportation system have resulted from improvements in aircraft and aircraft technologies. NASA's Fundamental Aeronautics Program is ensuring that, in the future, dramatic improvements can be derived from the next generation of aircraft.

New Flight Regimes

NASA is not fixated on developing new capabilities in just one flight regime, but instead believes that an ideal situation will exist when multiple vehicle types exist, each suited for a particular use, operating in an air transportation system that is flexible enough to accommodate a wide range of vehicles without limiting performance. Examples of some of the most promising concepts for large improvements in aviation include:

- Advanced subsonic/transonic transports with nearly half the fuel burn of current vehicles (and therefore half the greenhouse gas emissions), a noise footprint that can be confined to the boundary of the airport, and local emissions that are far below those encountered today. These gains will require revolutionary changes in the airframe and propulsion plant and the way in which they are integrated into a single system. Alternative sources of energy are likely to play a significant role in the development of these vehicles.
- Advanced supersonic transports with comparable performance to their subsonic/transonic counterparts and with low sonic boom characteristics so that the aircraft may be allowed to fly supersonically over land. In addition, takeoff and landing noise will be significantly reduced to meet or exceed Stage 4 requirements.
- Cruise-Efficient Short Take-Off and Landing (CESTOL) aircraft that cruise with very high performance and low environmental impact, yet can take off and land from very short runways.

- Advanced rotorcraft (large civil tiltrotors and variable-speed compound concepts) that allow vertical or short take-off and landing with vastly improved range and performance and reduced environmental impact (mainly from noise).

Knowledge/Technology Transfer

NASA believes "knowledge transfer" is critical and deserves high priority attention and a concerted effort to ensure it happens in a timely manner. Emphasizing "technology transfer" only drives a tendency to focus on devices and widgets, rather than on the knowledge enabling their creation. To ensure broad benefits to the community, the knowledge that underpins any new technology must be transferred to the community such that technology can be broadly applied. This "transfer" occurs at many levels ranging from the exchange of fundamental ideas to the adoption of new systems. We have created a number of mechanisms to enable such an exchange. For example, we have established technical working groups to engage industry and academic partners on a regular basis in order to facilitate knowledge transfer. Space Act Agreements are used to enable NASA to leverage industry's unique systems-level expertise while enabling industry to quickly acquire research results.

A new process has been established to help ensure that NASA's fundamental research can be transitioned for implementation in NextGen systems and concepts. NASA Aeronautics, the FAA, and the JPDO are working collaboratively to establish this process, which ensures research is sufficient and appropriate to enable NextGen. The new process has top-level commitment from the NASA Associate Administrator for Aeronautics and the FAA Vice President for Operations Planning Services, Air Traffic Organization. A coordinating committee that includes both FAA and NASA representatives oversees four initial Research Transition Teams (RTT) that are organized around the NextGen Concept of Operations framework. This framework connects the FAA's Operational Evolution Partnership elements with NASA research. The JPDO has an important role in the transfer in which they inform the Integrated Work Plan as work progresses. The teams are working to plan near-term R&D transition in areas such as surface management and long-term transition in areas such as dynamic airspace allocation. With regards to the initial collaborative RTT activity, more than 35 participants from FAA service units, NASA, MITRE/CAASD, and industry attended a workshop in Washington, DC in February 2008 to focus on integration of NASA and FAA research plans, schedules, roadmaps, and coordinated simulations for near-term NextGen Trajectory Management objectives.

In April 2008, NASA and FAA program, project, and senior researchers attended a RTT kick-off workshop focused on Surface ATM concepts. The primary goal of this RTT is to jointly collaborate on near- and mid-term objectives to reduce the risk of development of an Integrated Airport Surface/Arrival/Departure system concept for NextGen. Furthermore, NASA and FAA personnel are scheduled to conduct two additional RTT workshops early in the summer of 2008. In a fully collaborative effort, one workshop will work to define the far-term NextGen objectives of the dynamic airspace allocation concept, and the second will contribute to the definition of mid-term NextGen roles, responsibilities and objectives for the Multi-Sector Planner concept.

Following completion of the four pilot RTT workshops, NASA, FAA, and JPDO will make improvements to the RTT process based on lessons learned, and continue the collaboration of researchers and implementers to ensure that the research needed for NextGen is identified, conducted, and transitioned.

Building on NASA's Research Heritage

It is important to remember that NASA has a long heritage of conducting revolutionary research. The following are examples of NASA research that are making a difference in aviation today.

- NASA completed the first test of a digital fly-by-wire system in a modified F–8 Crusader aircraft in 1972. It was the forerunner of the fly-by-wire flight control systems now used on the Space Shuttle and on today's military and civilian aircraft to make them safer, more maneuverable and more efficient.
- Winglets are one of the most successful examples of NASA aeronautical innovation being utilized around the world on all types of aircraft. Winglets are vertical extensions of wingtips that improve an aircraft's fuel efficiency and cruising range.

- The FAA is engaged in national deployment of the NASA-developed Traffic Management Advisor (TMA) tool. TMA is now a component of the FAA's Free Flight program to increase the capacity of the Nation's airspace. The application enables en route air traffic controllers and traffic management specialists to develop complete arrival-scheduling plans. These plans help maximize an airport's use of available capacity by making early runway assignments for arriving aircraft and spacing aircraft so that they reach the airport at appropriate intervals.
- NASA's work improved aviation safety in hazardous weather conditions caused by wind-shear. In collaboration with industry and the FAA, NASA developed and validated on-board aircraft wind-shear sensors that could detect and measure the intensity of wind-shear conditions ahead of the aircraft, such that a pilot could be alerted in time to safely avoid a hazardous weather condition.

Figure 1 at the end of this testimony depicts some of these improvements along with others that have made a difference in the way we safely travel today.

Recent Accomplishments

After undergoing a thorough reformulation period, all of ARMD's programs are now in full implementation. The most important "thing" that these programs generate is knowledge. To validate our accomplishments and disseminate our results, we have placed a renewed emphasis on publication in peer-reviewed references and Program planning accounts for the effort needed to document research results. While there are too many success stories over the past two years to list, here are a few examples of recent accomplishments.

- In partnership with Boeing and the Air Force Research Laboratory (AFRL), the Fundamental Aeronautics Program successfully completed several flight tests of a blended wing body (BWB) aircraft, named X–48B, which has the potential to provide increased capacity, increased fuel efficiency and decreased noise compared to today's aircraft. The X–48B was cited as one of the "Best Innovations of the Year 2007" by *Time Magazine*.
- The Fundamental Aeronautics Program successfully demonstrated, in partnership with Pratt & Whitney, the feasibility of a high-efficiency fan design for an ultrahigh bypass ratio turbofan engine that, in combination with other technologies, has the potential for achieving significant noise reduction for aircraft.
- The Aviation Safety Program developed new data-mining tools to integrate and analyze large quantities of operational flight data to detect potential systemic problems across a fleet of aircraft. The ability to automatically detect and identify hidden anomalies or trends in aircraft systems will enable corrective action to be taken in a timely manner before an unsafe situation occurs.
- The Aviation Safety Program designed and built a new silicon carbide circuit chip that has exceeded 6,000 hours of continuous operation at 500 degrees Celsius (C) in a laboratory environment. The highly durable packaging of circuit chips is being developed to enable extremely functional but physically small and resilient circuitry that can provide constant engine health monitoring, even in the harsh conditions in the hot sections of jet engines.
- To better enable effective decision-making essential for NextGen, the Airspace Systems Program developed an aircraft-level flow control model to examine the impact of constraints (such as ground-delay decisions due to congestion) on flows into and out of New York area airports. The study examined variations in the geographical location of constraints, magnitude of constraints, and flow prioritization approaches, and found that prioritizing New York flows through congested sectors is possible without increasing system delays.
- The Airspace Systems Program developed an initial concept for Airspace Super Density Operations that meets the multiple objectives of NextGen terminal airspace operations: significantly increased capacity, robustness to varied and chaotic weather conditions, reduced environmental impact, and coordination of arrival and departure operations to/from multiple proximate airports. Initial assessments of core elements were conducted including: closely-spaced approach procedures, continuous descent arrival operations, 4D trajectory navigation, delegated spacing function and dynamic routing to avoid adverse weather.

Success Through Partnerships

NASA believes we should be in the leadership position to conduct fundamental research required to solve all the aeronautics challenges listed above. However, NASA also believes that we do this in close and strong partnerships with industry, academia and other government agencies in order to maximize the research capabilities of the Nation. Because these partnerships are so important, NASA has put many mechanisms in place to engage academia and industry, including industry working groups and technical interchange meetings at the program and project level, Space Act Agreements for cooperative partnerships with industry, and the NRA process that provides full and open competition for the best and most promising research ideas. Cooperative partnerships with industry consortia can result in a significant leverage of resources for all partners and can provide opportunities to test the value of component-technology advances in full system-level contexts. All research results, whether generated by NASA internally or by its partners through the NRA, will be openly disseminated through archival publications and conference proceedings as well as NASA publications to benefit broad U.S. aeronautics community while ensuring the dissemination policy is consistent with national security and foreign policy guidelines.

ARMD is actively using the NRA mechanism to foster collaboration with academia, industry, and non-profit organizations. The first Research Opportunities in Aeronautics NRA was released in May 2006 and since then two more versions have been issued on an annual basis. The response to the NRA has been tremendous. As of the end of April 2008, more than 1380 proposals have been received resulting in more than 327 awards. An important aspect of these awards is that they are closely aligned with the research goals of internal NASA efforts. This results in a cooperative arrangement that is mutually beneficial to NASA and to the performing organization. The NRA is based on the principle of full and open competition and provides an ideal mechanism for bringing the best ideas from across the Nation to bear on particular problems.

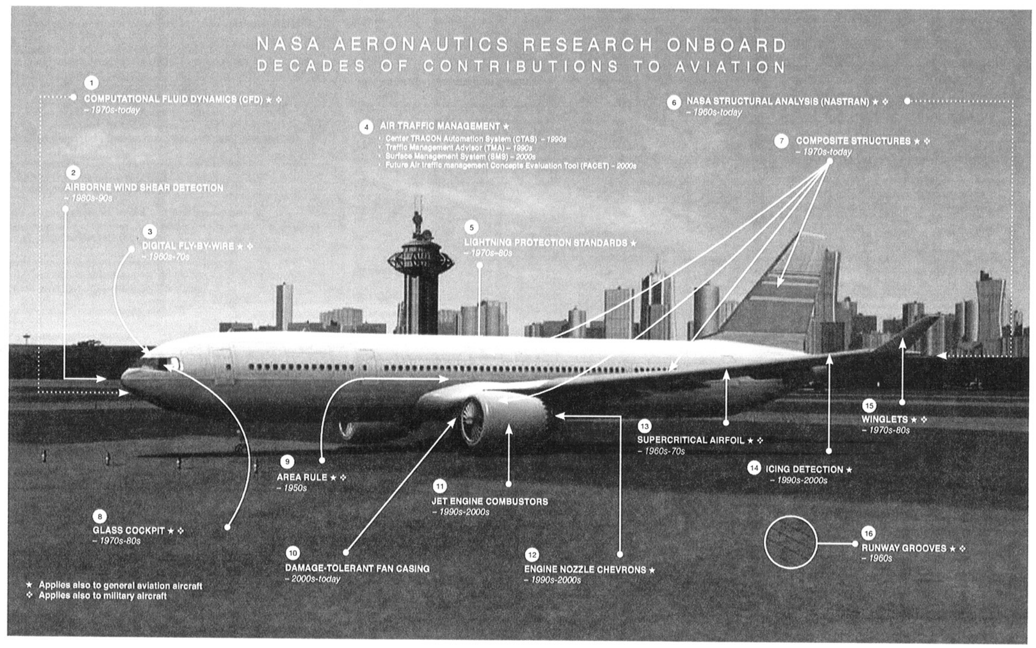
Last year, ARMD established over 30 Space Act Agreements with different members of the aerospace industry and, in some situations, with consortia of industrial participants. These collaborative opportunities have produced very significant research results at the system level where the expertise of industry and NASA come together to integrate technologies that can, one day, be incorporated into the aircraft fleet.

Finally, NASA recognizes the importance of close coordination not just with industry and academia, but with its partners in other government agencies as well. For example, NASA and the JPDO have established quarterly reviews to ensure close coordination, and NASA participates in all major JPDO planning activities. NASA and the FAA have developed a joint program plan for the Aviation Safety Information Analysis and Sharing (ASIAS) effort with well defined roles and responsibilities. NASA and the Department of Defense have signed an MOU to facilitate the establishment of an integrated national strategy for the management of their respective aeronautics test facilities. NASA and the U.S. Air Force have established an Executive Research Council that meets at least twice a year to ensure close coordination and collaboration. And lastly, NASA and the Army have signed a Memorandum of Understanding to coordinate research efforts on rotorcraft.

Conclusion

NASA Aeronautics is now in full execution of a robust fundamental research program that is well aligned with the National Aeronautics R&D Policy and directly supports the development of the NextGen system. NASA Aeronautics pursues long-term, cutting-edge research to address new challenges in the Nation's air transportation system and to support the Agency's space exploration vision. ARMD's commitment to technical excellence with strong partnerships with industry, academia and other government agencies will ensure our reputation as the world's premier aeronautics R&D organization.

National Aeronautics and Space Administration



www.nasa.gov

1. Computational Fluid Dynamics (CFD)
During the 1970s, NASA developed sophisticated computer codes that could accurately predict the flow of fluids using complex simulations, such as air over an aircraft's wing or fuel through a space shuttle's main engine.

Those codes became CFD, which today is considered a vital tool for the study of fluid dynamics.

CFD greatly reduces the time required to test and manufacture nearly any type of aircraft.

2. Airborne Wind Shear Detection
During the 1980s and 1990s, NASA led the first comprehensive research program to discover the characteristics of microburst and wind shear hazards.

The resulting NASA technology base led to the manufacture of on-board sensors that alert pilots in advance of wind shear hazards.

3. Digital Fly-by-Wire
During the 1960s and 1970s, NASA helped develop and flight test the digital "fly-by-wire" system, which replaced heavier and less reliable hydraulics systems with a digital computer and electric wires to send signals from the pilot to the control surfaces of an aircraft.

"Fly-by-wire" is used today on new commercial and military aircraft, and on the space shuttle.

4. Air Traffic Management
Over the decades, NASA has developed a number of air traffic management simulation tools, including:

Center TRACON Automation System (CTAS)
CTAS is a suite of software tools developed by NASA in the 1990s that generates new information for air traffic controllers.

Traffic Management Advisor (TMA)
TMA software, developed in the 1990s, forecasts arriving air traffic to help controllers plan for safe arrivals during peak periods.

Surface Management System (SMS)
SMS software, developed in the 2000s, provides controllers with data to know when aircraft arrive on the ground or at the gate.

Future Air traffic management Concepts Evaluation Tool (FACET)
FACET, developed in the 2000s, maps thousands of aircraft trajectories to improve traffic flow across the United States.

5. Lightning Protection Standards
During the 1970s and 1980s, NASA conducted extensive research and flight tests to collect the first comprehensive data on intra-cloud lightning strikes and the effects of in-flight strikes.

NASA's knowledge base is used to improve standards for protection against lightning for aircraft electrical and avionics systems.

6. NASA Structural Analysis (NASTRAN)
In the 1960s, NASA partnered with industry to develop a common generic software program that engineers could use to model and analyze different aerospace structures, including any kind of spacecraft or aircraft.

Today, NASTRAN is an "industry-standard" tool for computer-aided engineering of all types of structures.

7. Composite Structures
NASA first partnered with industry during the 1970s to conduct research on how to develop high-strength, nonmetallic materials that could replace heavier metals and aluminums on aircraft.

Composite materials have gradually replaced metallic materials on parts of an aircraft's tail, wings, fuselage, engine cowlings, and landing gear doors.

Using composite materials can reduce the overall weight of an aircraft and improve fuel efficiency.

8. Glass Cockpit
During the 1970s and 1980s, NASA created and tested the concept of an advanced cockpit display that would replace the growing number of dial and gauge instruments that were taking up space on an aircraft's flight deck.

Called a "glass cockpit," the innovative approach uses flat panel digital displays to provide the flight deck crew with a more integrated, easily understood picture of the vehicle situation.

Glass cockpits are in use on commercial, military, and general aviation aircraft, and on NASA's space shuttle fleet.

9. Area Rule
In the 1950s, NASA scientist Richard Whitcomb discovered several fundamental solutions to key aerodynamics challenges. One of the most revolutionary was the "area rule," a concept that helped aircraft designers avoid the disruption in air flow caused by the attachment of the wings to the fuselage.

Whitcomb deduced that removing the equivalent wing cross-sectional area from that of the fuselage cross-sectional area avoided the abrupt bump and improved the distribution of flow across the longitudinal area of the aircraft.

By using the area rule, aircraft designers for decades have been able to allow aircraft to fly higher, faster, and farther.

10. Damage-Tolerant Fan Casing
In the 2000s, NASA began spearheading research into developing a cost-effective turbofan jet engine casing that could be lighter, but still protect against possible fan blade failure inside the engine.

The solution was a fan case made of braided composite material that can reduce overall engine weight, increase safety, and improve aircraft structural integrity.

11. Jet Engine Combustors
During the 1990s and early 2000s, NASA improved the technology associated with jet fuel combustion to help engines burn fuel more cleanly.

The improved combustion helps reduce polluting emissions from aircraft engines, making them more environmentally friendly.

12. Engine Nozzle Chevrons
During the 1990s and early 2000s, NASA used computer simulations to improve an asymmetrical scallop design of chevrons used on the nozzles of jet engines.

Ground and flight tests by NASA and its partners proved that the new chevron design reduced noise levels in the passenger cabin and on the ground.

Chevrons are being implemented on many of today's aircraft, including the new Boeing 787.

13. Supercritical Airfoil
During the 1960s and 1970s, NASA scientist Richard Whitcomb led a team of researchers to develop and test a series of unique geometric shapes of airfoils, or wing designs, that could be applied to subsonic transport to improve lift and reduce drag.

The resulting "supercritical airfoil" shape, when integrated with the aircraft wing, minimizes drag and helps improve the aircraft's cruise efficiency.

14. Icing Detection
During the 1990s and early 2000s, NASA was called upon by the FAA to identify the characteristics of a dangerous and little-understood icing phenomenon called Supercooled Large Droplets (SLD).

Results from NASA flight tests and research were compiled in a large database to improve weather models and instrumentation for detecting SLD.

15. Winglets
During the 1970s and 1980s, NASA studies led to the development of vertical endplates that are now seen on many aircraft wings, or "winglets."

Winglets reduce vortices and drag, therefore improving airflow and fuel efficiency.

The first aircraft to adopt winglets were within the general aviation and business jet communities. In the mid-'80s, Boeing produced the 747-400 commercial jetliner, which used winglets to increase its range.

16. Runway Grooves
During the 1960s, NASA conceived and developed a process for cutting grooves along runways to channel away standing water.

The grooves proved successful in helping aircraft make safe landings on pavement made slick from rain, snow, or ice.

NASA's groove process was later adapted for use on military base runways, U.S. public highways, and even swimming pool decks, playgrounds, and floors of refineries.

Chairman UDALL. Thank you, Dr. Shin.
Mr. Meade.

STATEMENT OF MR. CARL J. MEADE, CO-CHAIR, COMMITTEE FOR THE ASSESSMENT OF NASA'S AERONAUTICS RESEARCH PROGRAM, NATIONAL RESEARCH COUNCIL

Mr. MEADE. Mr. Chairman, Members of the Subcommittee, thank you for inviting me here to testify today. My colleague, Dr. Donald Richardson, and I are co-chairs of the National Research Council's Committee for the Assessment of NASA's Aeronautics Research Program, and it is in that capacity that I appear to you today. Unless otherwise noted, the views I offer are strictly those of the Committee and not those of my employer, Northrop Grumman Corporation.

In addition to responding to the questions posed by the Subcommittee in its April 17th invitation to appear, which will be annotated in my written testimony, I would like to make some general observations.

Our committee evaluated NASA's entire aeronautics portfolio, both civil and non-civil. However, the majority of our attention was devoted to the request by Congress to assess NASA's aeronautics research program against a very specific benchmark, which was the Decadal Survey of Civil Aeronautics, published by the NRC in 2006. Therefore, most of our findings and recommendations are centered around that comparison.

The NASA aeronautics research program does have room for improvement, both in its direction and its execution. When assessing NASA's research against the recommendations of the decadal survey, we found mixed results. Our study found that NASA's efforts to achieve 20 of the 51 decadal survey technologies have no significant shortcomings or very minor shortcomings that are recoverable within the overall project concept and will substantially advance the state-of-the-art. Seven of the 51 have major shortcomings that would be difficult to recover within the current overall project concept. For the remaining 24 challenges, NASA is effectively addressing some areas but not others and so the results can best be described as mixed.

Your subcommittee specifically requested information regarding safety and environmental challenges. I will try to summarize those right now. Of the 20 challenges identified with little or no shortcomings, about half are related to safety or the environment. The same can be said for the other categories I just outlined, and this is consistent with the safety and environmental content of the entire set of 51 technology challenges, which is about half related to safety and the environment.

It would be easy to misinterpret our findings as largely negative. This is not the intent of the Committee, nor would it be proper interpretation to regard the results of our study as an indictment of the performance of NASA's Aeronautics Research Mission Directorate. Our committee would like to emphasize that by and large, we found the ARMD workforce to be both dedicated and competent.

Having said that, it does not appear that the ARMD has responded in any significant way to the recommendations of the decadal survey. Keep in mind, however, that the Decadal Survey of Civil Aeronautics was the first survey of its kind published in aeronautics. Consequently, ARMD has no experience in utilizing decadal surveys, which may help explain why the directorate did not respond immediately to its publication.

To properly understand our report, it is also important to keep in mind that the authors of the decadal survey itself were not bound by budgetary considerations, and this unlike decadal surveys from other scientific disciplines which we have seen in the recent past. Therefore, it is not unexpected that the ARMD would not be able to make progress on all 51 of the technology challenges contained in the decadal survey. In fact, barring an increase in funding for this activity, we have recommended that ARMD redefine its scope and address only the challenges with the highest priorities where significant, timely progress can be made in advancing the state of the art.

Aside from the quality of the research conducted by ARMD, we would stress the need for a cultural change within the directorate. Indeed, the Committee was most concerned about the lack of urgency demonstrated by some projects and the tendency of some researchers to assume that the ultimate consumer of the fruits of their labor was NASA itself. As one example, one of ARMD's three operating principles states, and I quote, "We will focus our research in areas that are appropriate to NASA's unique capabilities." In my opinion, NASA and the country would be better served if the principles were revised to include "We will mold NASA's unique capabilities to enable research in the most vital areas."

I will be glad to answer any questions you may have.

[The prepared statement of Mr. Meade follows:]

PREPARED STATEMENT OF CARL J. MEADE

Mr. Chairman, Members of the Subcommittee, thank you for inviting me to testify today. My colleague, Dr. Donald Richardson, and I are Co-Chairs of the National Research Council's Committee for the Assessment of NASA's Aeronautics Research Program. I appear here today in my capacity as Co-Chair of that committee. The views I share with you, are those of the Committee, not those of my employer, Northrop Grumman Corporation.

The Subcommittee's April 17, 2008 letter to me requesting this testimony posed three questions that are addressed below.

1. What were the major findings and recommendations of your recently completed assessment of NASA's fundamental aeronautics research program?

Our committee assessed the entirety of NASA's Aeronautics Research Program and made several recommendations to NASA to improve its ability to (1) meet the high-priority technology challenges that are identified in the *Decadal Survey of Civil Aeronautics,* which was published by the National Research Council in 2006, (2) address NASA's internal requirements for aeronautics research (e.g., to support robotic and human space exploration), and (3) satisfy non-civil aeronautics research requirements that NASA is addressing in agreement with other federal agencies and departments. The committee also addressed workforce expertise and research facilities relevant to the goals of NASA's Aeronautics research program.

The committee determined that the strategic objectives of the *Decadal Survey* are consistent with the key principles of the *National Aeronautics Research and Development Policy* (NSTC, 2006) and the *National Plan for Aeronautics Research and Development and Related Infrastructure* (NSTC, 2007). Thus, the recommendations below will also help achieve the goals of the *National Policy* and *Plan.*

Attachment 1 contains the full committee report, *NASA Aeronautics Research—An Assessment* (NRC, 2008), available online at *<www.nap.edu/catalog.php?record_id=12182>*.

RESOURCES VERSUS SCOPE OF RESEARCH

NASA supports a great deal of worthwhile research. However, NASA must determine how to respond to a vast array of worthwhile research possibilities within the constraints of budget, facilities, workforce composition, and federal policies. The *Decadal Survey of Civil Aeronautics* (NRC, 2006), recommended that NASA use the 51 highest-priority Research and Technology (R&T) challenges in the *Decadal Survey* as the foundation for the future of NASA's civil aeronautics research program during the next decade. However, the *Decadal Survey* was designed to identify the highest-priority R&T challenges without considering the cost or affordability of meeting the challenges.[1] As a result, even though the NASA aeronautics program has the technical ability to address each of the highest-priority R&T challenges from the *Decadal Survey* individually (through in-house research and/or partnerships with external research organizations), NASA's Aeronautics Research Mission Directorate (ARMD) would require a substantial budget increase to address all of the challenges in a thorough and comprehensive manner.

In addition to resource limitations, NASA's aeronautics research program faces many other constraints (in terms of the existing set of NASA centers, limitations on the ability to transfer staff positions among centers, and limitations on the ability to compete with the private sector in terms of financial compensation in some critical fields), and attempting to address too many research objectives will severely limit the ability to develop new core competencies and unique capabilities that may be vital to the future of U.S. aeronautics.

Recommendation. The NASA Aeronautics Research Mission Directorate should ensure that its research program substantively advances the state-of-the-art and makes a significant difference in a time frame of interest to users of the research results by (1) making a concerted effort to identify the potential users of on-going research and how that research relates to those needs and (2) prioritizing potential research opportunities according to an accepted set of metrics. In addition, absent a substantial increase in funding and/or a substantial reduction in other constraints that NASA faces in conducting aeronautics research (such as facilities, workforce composition, and federal policies), NASA, in consultation with the aeronautics research community and others as appropriate, should redefine the scope and priorities within the aeronautics research program to be consistent with available resources and the priorities identified in (2), above (even if all 51 highest-priority R&T challenges from the *Decadal Survey of Civil Aeronautics* are not addressed simultaneously). This would improve the value of the research that the aeronautics program is able to perform, and it would make resources available to facilitate the development of new core competencies and unique capabilities that may be essential to the Nation and to the NASA aeronautics program of the future.

ASSESSMENT RESULTS—MEETING THE R&T CHALLENGES

The basic planning documents for most of NASA's research projects were prepared before the *Decadal Survey* was published in 2006, and the NASA research portfolio, as a whole, does not seem to have changed course in response to the *Decadal Survey.* Thus, the content of the *Decadal Survey of Civil Aeronautics* appears to not have been a significant factor in the selection of the research portfolio being pursued by many of the ARMD's research projects.

NASA is doing a mixed job in responding to the 51 highest-priority R&T challenges in the *Decadal Survey of Civil Aeronautics.* In a few cases, the shortcomings noted by the Committee (both major and minor) indicate that NASA research plans are poorly conceived and the resulting research will likely be ineffective. In most cases, however, shortcomings reflect inconsistencies between NASA project plans and the *Decadal Survey.* These inconsistencies are generally the result of NASA choosing to do little or no work in a particular task area and/or selecting research goals that fall short of advancing the state-of-the-art far enough and with enough urgency either to make a substantial difference in meeting individual R&T challenges or the larger goal of achieving the strategic objectives of the *Decadal Survey of Civil Aeronautics.* However, as noted above, NASA does not have the resources necessary to address all 51 R&T challenges simultaneously in a thorough and comprehensive manner, and so (regardless of how the projects plans were developed) it is inevitable that the plans, as a whole, do not fully address all the priorities of the *Decadal Survey.*

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[1] Other decadal surveys that the NRC routinely produces for NASA in the space sciences consider budgetary factors in formulating their findings and recommendations, and it may be worthwhile to follow that model in future decadal surveys for aeronautics research.

WORKFORCE

There are—among NASA, the academic community, and the civilian aerospace industry—enough skilled research personnel to adequately support the current aeronautics research programs at NASA and nationwide, at least for the next decade or so. NASA may experience some localized problems at some centers, but the requisite intellectual capacity exists at the various centers and/or in organizations outside NASA. Thus, NASA should be able to achieve its research goals, for example, by using NASA Research Announcements or other procurement mechanisms; through the use of higher, locally competitive salaries in selected disciplines at some centers; and/or by creating a virtual workforce that integrates staff from multiple centers with the skills necessary to address a particular research task. The content of the NASA aeronautics program, which has a large portfolio of tool development but little or no opportunities for flight tests, may in some cases hamper the ability to recruit new staff as compared with the space exploration program. In addition, there will likely be increased requirements for specialized or new skill sets. Workforce problems and inefficiencies can also arise from fluctuations in national aerospace engineering employment and from uneven funding in particular areas of endeavor.

Recommendation. To ensure that the NASA aeronautics program has and will continue to have an adequate supply of trained employees, the Aeronautics Research Mission Directorate should develop a vision describing the role of its research staff as well as a comprehensive, centralized strategic plan for workforce integration and implementation specific to ARMD. The plan should be based on an ARMD-wide survey of staffing *requirements* by skill level, coupled with an *availability* analysis of NASA civil servants available to support the NASA aeronautics program. The plan should identify specific gaps and the time frame in which they should be addressed. It should also define the role of NASA civil servant researchers vis-à-vis external researchers in terms of the following:

- Defining, achieving, and maintaining an appropriate balance between inhouse research and external research (by academia and industry) in each project and task, recognizing that the appropriate balance will not be the same in all areas.
- Defining and addressing issues related to research involving multi-disciplinary capabilities and system design (i.e., research at Levels 3 and 4, respectively, as defined by ARMD).
- Ensuring that research projects continue to make progress when NASA works with outside organizations to obtain some of the requisite expertise (when that expertise is not resident in NASA's civil servant workforce).

NASA should use the National Research Council report *Building a Better NASA Workforce* (NRC, 2007) as a starting point in developing a comprehensive ARMD workforce plan.

FACILITIES

NASA has a unique set of aeronautics research facilities that provide key support to NASA, other federal departments and agencies, and industry. With very few exceptions, these facilities meet the relevant needs of existing aeronautics research. NASA also has a dedicated effort for sustaining large, key facilities and for shutting down low-priority facilities. However, some small facilities (particularly in the supersonic regime) are just as important as some larger facilities and may warrant more support than they currently receive. In addition, at the current investment rate, widespread facility degradation will inevitably impact the ability of ARMD projects and other important national aeronautics research and development to achieve their goals.

Recommendation. Absent a substantial increase in facility maintenance and investment funds, NASA should reduce the impact of facility shortcomings by continuing to assess facilities and mothball or de-commission facilities of lesser importance so that the most important facilities can be properly sustained.

2. Your report stresses the importance of ensuring that NASA's aeronautics research results are transferred to industry, the FAA, and other organizations that manufacture, own, and operate key elements of the air transportation system. What needs to be done to ensure that the transfer takes place in an efficient and effective manner?

USER CONNECTIONS

NASA civil aeronautics research will provide value to its stakeholders if and only if the results are ultimately transferred to industry, to the Federal Aviation Administration, and to the other organizations that manufacture, own, and operate key elements of the air transportation system. A closer connection between the managers of NASA aeronautics research projects and some potential users of NASA research would ensure that the need to transfer research results to users is properly considered in project planning and execution, and it would facilitate the formation of a coordinated set of research goals and milestones that are timed to meet the future needs of the Nation. In addition, for technology intended to enhance the competitiveness of U.S. industry, U.S. leadership would be enhanced by a technology-transfer process that does not necessarily include the immediate, public dissemination of results to potential foreign competitors, so that the U.S. industrial base has a head start in absorbing the fruits of this research.

Recommendation. The NASA Aeronautics Research Mission Directorate should bridge the gap between research and application—and thereby increase the likelihood that this research will be of value to the intended users—as follows:

- Foster closer connections between NASA principal investigators and the potential external and internal users of their research, which include U.S. industry, the Federal Aviation Administration, the Department of Defense, academia, and the NASA space program.
- Improve research planning to ensure that the results are likely to be available in time to meet the future needs of the Nation.
- Consistently articulate during the course of project planning and execution how research results are tied to capability improvements and how results will be transferred to users.
- For technology intended to enhance the competitiveness of U.S. industry, establish a more direct link between NASA and U.S. industry to provide for technology transfer in a way that does not necessarily include the immediate, public dissemination of results to potential foreign competitors.

As part of the effort to implement this recommendation, NASA should ensure that the Next Generation Air Transportation System (NGATS/NextGen) Air Traffic Management (ATM)–Airportal Project and the NGATS ATM–Airspace Project meet the research and development (R&D) needs defined by the NextGen Joint Planning and Development Office (JPDO) for NASA.[2]

3. Do you have any recommendations for the Committee to consider as we prepare to draft a NASA reauthorization bill?

NASA has a critical part to play in preserving the role of the United States as a leader in aeronautics. NASA research facilities and expertise support research by other federal agencies and industry, and the results of research conducted and/or sponsored by NASA are embodied in key elements of the air transportation system, military aviation, and the U.S. space program. NASA aeronautics research will carry on this tradition as long as its research is properly prioritized and research tasks are executed with enough depth and vigor to produce meaningful results in a timely fashion. Accordingly, the effectiveness of NASA's aeronautics research would be enhanced by Congressional direction to implement the high-priority research challenges in the *Decadal Survey of Civil Aeronautics.* Congress may also choose to relax the constraints that limit the ability of NASA to implement a more robust aeronautics research program. As noted above, constraints of particular interest include the budget, facilities, workforce composition, and related federal policies.

[2] The Next Generation Air Transportation System is now most commonly abbreviated as NextGen, but the titles of NASA's related research projects still feature the old acronym, NGATS.

Attachment 1

NASA Aeronautics Research
AN ASSESSMENT

Committee for the Assessment of NASA's Aeronautics Research Program

Aeronautics and Space Engineering Board

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

The National Academies Press
Washington, D.C.
www.nap.edu

Copies of the National Research Council report, NASA Aeronautics Research—An Assessment, *are available separately and can be downloaded for no cost from* <www.nap.edu/catalog.php?record_id=12182>.

BIOGRAPHY FOR CARL J. MEADE

Mr. Meade is currently the Director of Space Systems at Northrop Grumman Corporation's Integrated Systems sector in El Segundo, California. He and his team are responsible for the capture and execution of various government projects relating to crewed space flight and non-payload military space vehicles. He was previously employed at Lockheed Martin Aeronautics Company (aka "Skunk Works") in Palmdale, California where he was responsible for the development of a portfolio of advanced aerospace vehicles. He also held numerous positions on the X–33 program—first as Flight Assurance Manager, then as Operations Manager, and finally as the Program Director. Immediately prior to his arrival at Lockheed Martin, Carl was an Air Force officer on astronaut duty with NASA.

Carl began his aerospace career as a Hughes Fellow at the California Institute of Technology. After completing his graduate degree, Carl continued employment at Hughes Aircraft Company as an electronics design engineer. He was then called to active military duty and flew tactical fighter aircraft in the U.S. Air Force. He was selected for test pilot training in 1980 and graduated first in his class at the USAF Test Pilot School at Edwards AFB.

While assigned to the Air Force Flight Test Center, Carl tested various fighter aircraft and instructed at the USAF Test Pilot School. Selected as an astronaut in June 1985, Carl was assigned to the NASA Johnson Space Center in Houston where he held a variety of technical and leadership assignments. He flew as an Astronaut on Space Shuttle missions STS–38, STS–50 and STS–64. During an untethered space walk on STS–64, he performed the first flight-test of a rescue jet-pack and was consequently awarded the Air Force Distinguished Flying Cross.

Carl has authored several publications and is a member of the Society of Experimental Test Pilots and the Association of Space Explorers. He has served as a member of the National Research Council's committee evaluating the National Aerospace Initiative and also on committee assessing NASA's Aeronautics Research Mission Directorate. He holds an undergraduate degree in Electrical Engineering from the University of Texas at Austin, and a graduate degree in the same field from the California Institute of Technology. During most weekends, you can find Carl teamed with his wife, Celyna, and sons David, Jacob and Michael in a futile attempt to convert their patch of Mojave Desert into a tropical oasis. Between tours of duty in the yard, Carl finds that the experimental aircraft currently under construction in his shop provides ample opportunity to consume all remaining free time.

Chairman UDALL. Thank you, Mr. Meade.

Mr. Henne.

STATEMENT OF MR. PRESTON A. HENNE, SENIOR VICE PRESIDENT, PROGRAMS, ENGINEERING AND TESTING, GULFSTREAM AEROSPACE CORPORATION

Mr. HENNE. Mr. Chairman, Members of the Subcommittee, thank you for this opportunity to testify before your committee.

My employer, Gulfstream Aerospace, is headquartered in Savannah, Georgia, with some 9,800 employees. Gulfstream is a $5 billion annual revenue company that designs, builds and services premium business aircraft. We have major facilities in eight states within our continental borders. Gulfstream has a current product line of seven different models ranging in price from $14 million to $59 million. Our primary competitors are Canadian with Bombardier, French with Dassault and Brazilian with Embraer.

Foreign countries and businesses recognize the huge value associated with strong aeronautics enterprise. You have already—both the Members have identified the value of aeronautics today and I won't delve into that. But foreign countries recognize and invest in national aeronautics enterprises. The United States seems to take aeronautics for granted, often describing it in political circles as a mature industry, able to fend for itself in terms of continuing R&D needs. I suspect, however, that we should not be ready to close the aeronautical patent office.

To give one grand example, successful civil supersonic transportation is still to be achieved, yet we continually see decreasing NASA aeronautics R&D budgets. Over the past 10 years funding in NASA aeronautics research has declined by some 48 percent from over $1 billion to somewhere around $622 million today. The United States is down to one civil aircraft manufacturer and doesn't even participate in the regional jet manufacturing market. Gulfstream used to be alone in the large cabin business jets. We now have three strong foreign competitors intent on capturing our market. More importantly, they are keen on capturing the engine for jobs and economic growth.

Why is it important for the Federal Government to invest in aeronautical R&D? The aeronautics enterprise contribution to jobs, to tax revenues, to favorable balance of trade, as you, Mr. Chairman, have already mentioned, is massive. The recent Executive Order establishing a national aeronautics R&D policy states, "Continued progress in aeronautics, the science of flight, is essential to America's economic success."

Congress in 1958 directed that government-sponsored aeronautical activities be conducted to contribute materially to specific objectives including the following: improvement of the usefulness, performance, speed, safety and efficiency of aeronautical vehicles and the preservation of the role of the United States as a leader in aeronautical technology.

The role of federal investment in aeronautics is to advance U.S. technological leadership, to lead innovation and to develop advanced aeronautics concepts and technologies. It is the catalyst for progress.

In the past, NASA aeronautics has served as a great source of aeronautical R&D efforts. Dr. Shin mentioned some of those. However, with the ever-decreasing budgets, this pipeline is drying up. In recent years, even vehicle technology demonstrations, a vital risk reduction link between basic R&D and product application, have been terminated. This has been a substantial blow to maturing aeronautical technologies and for U.S. companies involved. Clearly, our aeronautics program needs a revitalization effort to address existing priorities and to address the insufficient aeronautics research funding.

How do we ensure that it is relevant? The following considerations are put forth. An understanding that the status quo with ever-reducing budgets isn't working. NASA aeronautics needs to work beyond just fundamentals and take a continuing role in technology demonstration, and the split, the public-private funding participation, needs to be more balanced in an equitable situation.

According to a recent article in a well-respected trade publication, government versus private expenditures for all U.S. R&D have virtually reversed themselves in the last 45 years. In 1964, the government funded 64 percent of all R&D. In 2006, industry funded 66 percent, or roughly $220 billion in R&D funding.

Specifically, NASA's aeronautics budget should be increased to fund research into NextGen. We have already heard that. Environment research, we have heard that. In aviation safety, NASA clearly plays an important role in all of those areas.

In opening new flight regimes, NASA should be leading the way. Frankly, what more important leadership role can NASA aeronautics have? As mentioned earlier, we have yet to achieve successful supersonic civil transportation. To achieve that really requires improvements in aeronautical technology, technology demonstrations. This is what NASA aeronautics has historically excelled in and should continue to excel in. Risk reduction and barrier removal in R&D focused on new flight regimes is a strong inducement for commercial growth, job creation and protecting the national aeronautics leadership position.

In closing, my recommendations are: that the budget for NASA aeronautics must increase substantially, the reestablishment of

NASA aeronautics as a vital R&D activity; a high-priority activity supporting a broad group of U.S. companies needs to happen; NASA aeronautics procurement policies need to allow commercial contracting practices; U.S. Government action to minimize foreign competitor advantages due to strong financial aid needs to occur; and separation of aeronautics activity out of the space agency as a means to implement a strong aeronautics R&D policy needs to be considered.

Mr. Chairman, thank you for the opportunity to express these views, and I look forward to your questions.

[The prepared statement of Mr. Henne follows:]

PREPARED STATEMENT OF PRESTON A. HENNE

Mr. Chairman, Members of the House Space and Aeronautics Subcommittee:

It is a pleasure to be here today to discuss the status of NASA's Aeronautics program.

By way of introduction, my name is Preston Henne and I am Senior VP of Programs, Engineering and Test at Gulfstream Aerospace. Gulfstream headquarters are in Savannah, GA and has roughly 9800 employees. Gulfstream is a $5B annual revenue company that designs, builds and services premium business aircraft. Gulfstream proudly has facility sites in eight states within our continental borders. Our supply chain is extensive and accounts for supplier employees in literally every state, producing goods and services in support of our product line. Gulfstream has a current product line of seven different models ranging in price from $14M to $59M. Our primary competitors are Canadian (Bombardier), French (Dassault), and Brazilian (Embraer).

In the 105 years of flight, aeronautics has become integral to the world's culture. Aeronautical products and services touch nearly everyone in the world in one way or another. The U.S. leadership in developing and applying aeronautical technology over the last 100 years is indisputable. This leadership has provided remarkable commercial growth and economic opportunity for millions and millions of people in the U.S. However, this aeronautical leadership and, more importantly, the opportunities associated with it, are being strongly challenged by foreign competition in the world market place.

Foreign countries and businesses recognize the huge value associated with a strong aeronautics enterprise, and are clearly willing to invest national as well as corporate treasuries to grow it. The U.S., on the other hand, seems to take the aeronautics enterprise for granted. It is often described in political circles as a mature industry and able to fend for itself in terms of continuing R&D needs. I suspect, however, that we should not be ready to close the aeronautical patent office. As but one grand example, financially successful and environmentally acceptable civil supersonic transportation is still to be achieved. Yet, we see continually decreasing NASA Aeronautics R&D budgets. To illustrate this point, the downward federal budget trend of the past decade for this account continues for the current fiscal year. The President's FY09 request for aeronautics research represents a 28 percent decline over the appropriated level of FY08, which in turn was 30 percent lower than the previous year. Over the last ten years, funding for NASA Aeronautics research has declined by some 48 percent, from $1.2B in 1999 to $622M in FY08.

The U.S. is down to one large civil aircraft manufacturer and no longer even participates in the regional jet market as a manufacturer. Gulfstream used to be alone in the market for large cabin business jets. We now have three strong foreign competitors that are intent on capturing our market. More importantly, they are keen on capturing the engine for jobs and economic growth.

So, why is it important for the Federal Government to invest in aeronautics R&D? A strong aeronautics industrial base provides huge economic value. The aeronautics enterprise contribution to jobs, to tax revenues, to favorable balance of trade is massive. The recent Executive Order establishing a National Aeronautics R&D Policy states: "Continued progress in aeronautics, the science of flight, is essential to America's economic success . . ." Congress, in the original creation of NASA in the *National Aeronautics and Space Act of 1958,* directs that: "Government-sponsored aeronautical activities be conducted to contribute materially to specific objectives, including the following:

- improvement of the usefulness, performance, speed, safety, and efficiency of aeronautical . . . vehicles;
- preservation of the role of the United States as a leader in aeronautical . . . technology."

The role of federal investment in aeronautics is to advance U.S. technological leadership, to lead innovation, and to develop advanced aeronautics concepts and technologies. It is the catalyst for progress.

In the past NASA Aeronautics served as a great source of aeronautical R&D efforts. NASA aeronautical technology has found its way into the market place in multiple forms and in numerous products. With ever decreasing budgets, however, this pipeline is drying up. In recent years, even vehicle technology demonstrations, a vital risk reduction link between basic R&D and product application, have been terminated. This has been a substantial blow to maturing aeronautical technologies and for U.S. companies involved.

Clearly, our nation's aeronautics program needs a revitalization effort to address our existing priorities and the insufficient aeronautics research funding.

How do we ensure NASA's aeronautics program is relevant? In making NASA aeronautics more relevant to our nation's needs, the following considerations are put forth:

- A tacit understanding that the status quo, with ever reducing budgets, isn't working
- NASA aeronautics needs to work beyond just "fundamentals" and needs to take a continuing role in technology demonstration
- Public-private funding participation needs to be balanced along more equitable conditions

As an example, a recent viewpoint article in a well-respected trade publication stated that government versus private expenditures for all U.S. R&D have virtually reversed themselves over the past 45 years. In 1964, the government funded 64 percent of all R&D—by 2006, industry funded some 66 percent of the total, or roughly $220 billion in R&D funding.

The following points offer some specifics:

- *NextGen Research Needs*

NASA and the Federal Aviation Administration (FAA) are coordinating research to help implement the Next Generation Air Traffic Control System, known as NextGen, which will use satellite technology to increase capacity and efficiency within the airspace. Since NextGen is scheduled for completion by 2020—when air traffic is expected to double—it is essential that Congress provide NASA with adequate funding now so that it can meet its research obligations over the next ten years.

Specifically, NASA's Aeronautics budget should be increased to help fund research into:

- Airspace management
- Reduced separation/vortex wake alleviation
- High density arrival technology
- Roles of air traffic controllers, automated decision-making and conflict resolution

- *Environmental Research Needs*

NASA research has produced advances in engine and airframe performance that have helped reduce emissions and lower noise. These efforts need to be enhanced and expanded. NASA research should also be focused around the development of:

- Alternative low carbon life cycle aviation fuels
- Methods to make more efficient use of airspace that will help reduce emissions, including Continuous Descent Approaches and improved in-flight re-planning capabilities
- New methods to reduce noise, specifically with regard to supersonic flights

- *Aviation Safety Research Needs*

NASA plays a critical role in developing important safety enhancing technologies including infrastructure needed for FAA and industry aircraft certification. Key areas of focus should include complex hardware and software certification, human/automation interface, and aircraft separation management.

How can NASA work most effectively with industry and the universities? To work effectively with industry and universities NASA needs to play to their strengths and interests. NASA has repeatedly developed aeronautical technology plans and road maps for high priority research subjects of national interest. These road maps need to lead to companies and universities with appropriate interest and expertise. These roadmaps need to turn into aeronautical R&D Programs up to and including large scale demonstrations. These programs need to satisfy both NASA and company or university objectives . . . and they need to be funded. NASA needs to provide significant funding to assure innovation, to assure risk reduction, and to assure broad dissemination of results. In order to enable broad participation of interested companies, enhanced contracting policies need to admit commercial practices.

What role should NASA play in opening new flight regimes? On the question of opening new flight regimes, NASA should be leading the way. Frankly, what more important leadership role can NASA Aeronautics have? As I mentioned earlier, we have not yet achieved successful civil supersonic transportation. Successful in this context means technically, environmentally, and economically successful. To make the leap to a substantial transportation speed increase, new environmental and safety standards are needed. Aeronautical technology improvements are needed. Technology demonstrations are needed. This is what NASA Aeronautics has historically excelled in and should continue to excel in. The risk reduction and barrier removal R&D focused on new flight regimes is a strong inducement for commercial growth, jobs creation, and protecting the national aeronautics leadership position.

Recommendations and Closing Remarks

As the Subcommittee continues its very important work in producing a NASA Reauthorization Bill, I wish to leave you with the following recommendations:

(1) That the budget for NASA's Aeronautics Directorate be increased for FY09 to $700M—this would constitute nearly an $80M increase over the approved FY08 level. Further, this increase would support the 2005 National Academy of Sciences report, *Rising Above the Gathering Storm,* which recommended an increase by at least ten percent annually to keep America's economy competitive.

(2) Re-establishment of NASA Aeronautics as a vital R&D activity supporting a broad group of U.S. aeronautics companies.

(3) Enhance NASA Aeronautics procurement policies to allow commercial contracting practices.

(4) U.S. Government action to minimize foreign competitor advantages due to strong financial aid.

(5) Separation of the aeronautics activity out of the space agency as a means to implement a strong aeronautics R&D policy.

Mr. Chairman, Members of the Space and Aeronautics Subcommittee, I thank you for the opportunity to express these views on what we believe to be important to our future. I look forward to your questions.

Biography for Preston A. Henne

Preston "Pres" Henne is Senior Vice President for Programs, Engineering and Test at Gulfstream. He also is a Vice President of General Dynamics Corp.

Henne began his aerospace career in 1969 at McDonnell Douglas, where he managed several advanced programs in aerodynamics and acoustics for both military and commercial aircraft. Known for his work in advanced aerodynamic technology, he was responsible for the aerodynamic design of the wing on the C–17—considered the most versatile aircraft in airlift history and winner of the 1994 Collier Trophy for aeronautical achievement. Henne later served as Chief Design Engineer for the MD–80 aircraft. In 1991, he became Vice President and General Manager of the MD–90 Program at McDonnell Douglas' Long Beach Douglas Aircraft facility, where he oversaw the aircraft's complete development and certification process.

Joining Gulfstream in 1994, Henne is credited with the design, development, test and certification of the Gulfstream V aircraft—which was awarded the 1997 Collier Trophy. Henne became a Vice President of General Dynamics in July 1999 when the company acquired Gulfstream. As Senior Vice President, Programs, Engineering and Test, he is responsible for Gulfstream's product program management, engineering, and flight operations. His organization was responsible for the development of the Gulfstream 550—which was recognized with the Collier Trophy in 2003.

Henne earned a Bachelor's degree in aeronautical and astronautical engineering with highest undergraduate honors from the University of Illinois in 1969 and a Master's degree in engineering from California State University at Long Beach in 1974. He is a member of the Innovation Leadership Advisory Board (ILAB) at the University of Illinois College of Engineering and of the Georgia Tech Research Corporation Board of Trustees. Henne is a Fellow of the American Institute for Aeronautics and Astronautics (AIAA) and a Fellow of the Royal Aeronautical Society. His awards include the AIAA Engineer of the Year Award in 1996 and the AIAA Hap Arnold Award in 2001 for excellence in aeronautical program management. He has been elected to the National Academy of Engineering in 2004. In 2005 the University of Illinois recognized Henne with the Alumni Award for Distinguished Service.

Chairman UDALL. Thank you, Mr. Henne.

Dr. Kroo.

STATEMENT OF DR. ILAN KROO, PROFESSOR, DEPARTMENT OF AERONAUTICS AND ASTRONAUTICS, STANFORD UNIVERSITY

Dr. KROO. Mr. Chairman and Members of the Committee, thank you for the opportunity to testify on NASA's aeronautics research program.

I teach at Stanford University and conduct research related to future aeronautical concepts. My familiarity with NASA's research program comes from continuing interactions during my career at Stanford and participation in several studies by the National Research Council including the *Decadal Study of Civil Aeronautics* in 2006.

I will focus my comments on three questions suggested by the Committee. The first question was, what are the most important challenges to be addressed if the Nation is to sustain an efficient, environmentally compatible and safe aviation system and what should NASA's role be in addressing these challenges. Well, as noted by my colleagues and the Chair, the Nation's air transportation system has been a critical engineer for our economy and quality of life for many decades. Commercial aircraft have made dramatic improvements in cost, safety and efficiency over the last 50 years. However, the growing global demand for air travel and the impact of this growth on the environment have led us to a critical point in the evolution of aviation.

Even today, system capacity limitations, the cost of fuel and local environmental impact are clear problems. It will certainly not be possible to sustain an acceptable system in the future without significant technical advances. The greatest challenge will be to accommodate the anticipated growth in air travel without increasingly problematic global and local environmental impact.

This is not just a regulatory problem. It requires long-term research and development of new technologies spanning multiple disciplines. In many ways, NASA is ideally positioned to address these problems. No other agency or industry has the experience and tools to both study the impact of aviation on the global environment and to develop technologies that may be needed in the future aircraft engine, airframes and air traffic management systems. Unfortunately, the magnitude of the problem is great and growing, and NASA's aeronautics program is not.

This brings us to the second question. The adverse impact of aviation on the environment has long been a concern and that concern has recently expanded to include the impact of aviation on climate. What are the most promising R&D avenues for addressing these concerns and what should NASA's R&D priorities be in this area? Well, in terms of efficiency and environmental impact, commercial aviation can be considered a real success story. A few decades ago, fuel usage per passenger mile was about 70 percent greater than it is today. A flight across the country in a new 737 now requires only about 29 gallons of gasoline or kerosene per person, and that is about 80 passenger miles per gallon. Unfortunately, the trouble is that trillions of passenger miles are flown each year and that traffic is expected to double over the next 20 years. So although aviation currently accounts for two to four percent of human CO_2 emissions, its impact on the environment may be much greater in the future due to this projected growth, pollutants other than CO_2 and the disproportionate effect of emissions at high altitudes. Local and regional environmental effects such as airport community and local air quality will also be aggravated by the projected increase in air travel.

So in order to achieve a sustainable aviation system while accommodating increasing demand, dramatic improvements in aircraft efficiency are required. Unfortunately, most of the easy steps have already been taken and further advances require research into better modeling and design capabilities, new configuration concepts, improved flight management systems and alternative fuels that are well suited to aviation use. Many uncertainties also remain in the effects of aviation on the atmosphere, and research is also required to determine just how to minimize the impact of air travel in the future. Specific aggressive but rational targets for aircraft noise and emissions should guide the research priorities for NASA. Goals such as those described in the National Plan for Aeronautics R&D published last December are clearly affecting NASA's research plans, but cutting fuel consumption and noise by 50 percent is very difficult and it is not clear that this can be achieved with the Agency's current resources.

So what does NASA need to do so that its aeronautics R&D activities can be effectively transitioned to the public sector? Well, in the past few years, NASA has done a good job in defining a strong fundamental research program within severely limiting budget constraints. It has focused R&D activities on the kind of fundamental research that will be important for longer-term solutions, but if the goal is to actually create a future system that will work, not just write great research papers, much more is needed. The next step is to understand how some of the most promising technologies can be integrated at the system level and transitioned from the lab to the user. These critical integration and validation projects will require close collaboration with industry but it is difficult to see how they can be undertaken with NASA's current level of investment in aeronautics.

Again, thank you, Mr. Chairman, for the opportunity to testify, and I will be happy to answer questions.

[The prepared statement of Dr. Kroo follows:]

PREPARED STATEMENT OF ILAN KROO

Mr. Chairman and Members of the Committee, thank you for the opportunity to testify on NASA's aeronautics research program. My name is Ilan Kroo. I teach at Stanford University and conduct research related to future aeronautical concepts.

My familiarity with NASA's research program stems from work as a civil servant at NASA's Ames Research Center twenty years ago, continuing interactions with NASA during my research career at Stanford, and participation in several related studies by the National Research Council, including the *Decadal Survey of Civil Aeronautics* in 2006.

I will focus these comments on NASA's role in research to improve the safety and reduce the environmental impact of our future air transportation system, addressing questions posed in your letter of April 17, 2008.

What do you consider to be the most important challenges to be addressed if the Nation is to sustain an efficient, environmentally compatible, and safe aviation system? What should NASA's role be in addressing these challenges?

The Nation's air transportation system has been a critical engine for our economy and quality of life for many decades. In terms of cost, safety, and efficiency, commercial aircraft have made dramatic improvements over the last fifty years. However, the growing global demand for air travel, the constraints imposed on system capacity, and the impact of this growth on the environment have led us to a critical point in the evolution of aviation. Even now, issues with system capacity, the cost of fuel, and local environmental impact make it clear that it is not possible to sustain an acceptable system without significant technical advances. The greatest challenges will be to accommodate the anticipated two to threefold growth in air travel over the next twenty to thirty years without increasingly problematic local and global environmental impact. The growing diversity of air vehicles, from personal aircraft and light jets to regional jets and very large aircraft, potentially larger numbers of unmanned aircraft, and even supersonic aircraft make this challenge even more complex. Since these long-term issues cannot be solved by regulation alone and require the development of technologies that span multiple industries, the critical research is very appropriate for NASA to undertake. In many ways NASA is uniquely positioned to address some of these problems. No other agency or industry has the expertise and tools to study the impact of aviation on the global environment along with technologies that may be needed for future aircraft engines, airframes, and traffic management systems. Unfortunately the magnitude of the problem is great and growing, while NASA's aeronautics program is not.

The adverse impact of aviation on the environment has long been a concern, and that concern has recently expanded to include the impact of aviation on climate. What do you consider to be the most promising R&D avenues for addressing environmental concerns associated with aviation, and what should NASA's R&D priorities be in this area?

In many ways commercial aviation is a success story in terms of efficiency and environmental impact. A few decades ago fuel usage per passenger mile was about 70 percent greater than it is today and the next generation of aircraft should reduce fuel consumption by 20 percent compared with today's aircraft. A flight across the country in a Boeing 737–800 requires only about 29 gallons of fuel per person (a per-person mileage of about 80 miles per gallon).

However, trillions of passenger-miles are flown each year and traffic is expected to double over the next twenty years. So, although aviation currently accounts for only about two to four percent of human CO_2 emissions, its impact on the environment may be much greater in the future due to this projected growth, pollutants other than CO_2, and the disproportionate effect of emissions deposition at high altitude. In order to achieve a sustainable aviation system while accommodating increasing demand, dramatic improvements in aircraft efficiency are required. Unfortunately, most of the easy steps have been taken and further improvements require research into better modeling and design capabilities, new configuration concepts, and alternate fuels that are well-suited to aviation use. Many uncertainties remain about the effects of aviation on the atmosphere, and research is required to determine how to minimize the impact of air travel in the future. Nearer-term problems, aggravated by increasing demand and alleviated with some of the technology advances noted above, include local and regional environmental effects such as airport community noise and local air quality.

NASA's fundamental research work addresses some of these issues, but needs to be expanded and focused on the most promising technologies if it is to contribute in a significant way to solving these problems. Specific, aggressive, but rational targets for future aircraft noise and emissions should guide the research priorities for NASA's research. Challenging goals such as those described in the *National Plan for Aeronautics R&D,* published last December are clearly affecting NASA's research plans, but it is not clear how they can actually be achieved with the Agency's current resources.

Will it be possible for a Next Generation Air Transportation System [NextGen] to meet anticipated demand without incurring additional environmental degradation? If so, how?

Some of the problems with increasing demand are obvious to travelers today, with flight delays and cancellations affecting the entire system. The importance of improved air traffic management to achieve a safe and efficient system, even as demand grows, is very clear. Perhaps less obvious is the role that future traffic management systems can play in reducing aviation's environmental footprint. Exploiting recent advances in reliable precision navigation to guide aircraft on routes that produce less noise, consume less fuel, or even to avoid regions with more sensitive atmospheric conditions may minimize both local and global environmental effects. Increased vehicle autonomy can enable real-time re-planning and more optimal flight paths without increasing pilot workload or compromising safety. NASA's fundamental work in this area is important but needs to progress to the next steps involving larger scale experiments and validation. Furthermore, although improved management of traffic is necessary in a next generation air transportation system, this alone will not be sufficient to meet the stringent environmental constraints that we expect in the future. Part of NASA's work in NextGen must be to combine new vehicle concepts that achieve unprecedented efficiency levels, with a traffic management system that can properly accommodate legacy aircraft and advanced designs that may fly at different altitudes and speeds. This has been recognized within NASA, but must be emphasized.

What does NASA need to do so that its aeronautics R&D activities can be effectively and more rapidly transitioned to the marketplace or to the public sector users, as the case may be?

In the past few years NASA has done a good job in defining a strong, fundamental research program within severely-limiting budget constraints. It has focused R&D activities on the kind of fundamental research that will be important for longer-term solutions. The next step is to understand how some of the most promising technologies can be integrated at the system level and transitioned from the lab to the user. These critical integration and validation projects will require close collaboration with industry and it is difficult to see how they can be undertaken with NASA's current level of investment in aeronautics.

Again, thank you Mr. Chairman, for the opportunity to testify.

Biography for Ilan Kroo

Dr. Ilan Kroo is a Professor of Aeronautics and Astronautics at Stanford University, where he directs the Aircraft Aerodynamics and Design Group. He received his Bachelor's degree in Physics from Stanford in 1978, and continued studies in Aeronautics, leading to a Ph.D. degree in 1983. Prior to joining the Stanford faculty, he was a Research Scientist in the Advanced Aerodynamic Concepts Branch at NASA's Ames Research Center in California. Dr. Kroo's research includes the application of new computational architectures for high-fidelity optimization and studies of unconventional configurations including new concepts for efficient subsonic and supersonic aircraft. Dr. Kroo is a Fellow of the AIAA, received the AIAA Lawrence Sperry Award in 1990, the Outstanding Teacher Award in 1994, and the Dryden Lectureship in Research in 2003. He is a member of the National Academy of Engineering and the Air Force Scientific Advisory Board and is Chief Scientist of the Aerion Corporation.

Discussion

Additional Funding for NASA Aeronautics

Chairman Udall. Thank you, Dr. Kroo.

At this point we want to move right to our first round of questions. I am going to recognize myself for five minutes, and I want to turn back to our final witness, Dr. Kroo.

Each of you, with the exception of Dr. Shin, who is being a loyal representative of the Administration, has highlighted the negative impacts of the declining NASA aeronautics budget. If NASA's aeronautics program were to be given a higher level of funding on a sustained basis, not just a one-year infusion of cash but on a higher baseline funding level, by this Congress or the next Administration, what would be the most productive uses for that additional funding? What do you consider to be the most important priorities to pursue? Maybe we can move from my right to my left, starting with Dr. Kroo.

Dr. KROO. Well, as I mentioned, I believe that the issue of future technologies for reducing environmental impact are some of the most important areas for NASA to be working on, and if given a larger budget, NASA needs to proceed from the kind of fundamental research that they are doing very well to more research that can be used by the industry to actually achieve some of the goals that have been stated. So progressing from fundamental research to integration, system-level research and validation experiments and research work is a critical aspect of that.

Chairman UDALL. I will move to Mr. Henne. You have advocated, what, an $80 million or so increase over last year's approval level. What critical research projects would you target with that increase? You have to turn your microphone on, if you would.

Mr. HENNE. Sorry. I think you have some goals of the country with the environmental impact, with NextGen, with safety, and frankly, those should be the outcomes. What needs to happen is an investment in advanced technology and advanced concepts. It is with the vehicles you are going to achieve the improvements in the environment, the improvements in safety, the improvement in the ATC operation. It has to come from the vehicles. And so my look at that would be, we need to do more in advanced concepts and vehicle technology.

Chairman UDALL. Mr. Meade, would you care to comment?

Mr. MEADE. Yes, Mr. Chairman. Our committee was asked to specifically concentrate on the decadal survey so with respect to that framework, I would like to answer that. I think if you read our report, what you will find is that concentration and fuel efficiencies and NextGen enablers would be at the top of the list in addition to all of the safety efforts within the decadal survey, the 51 challenges, and those safety efforts come down to basically collision avoidance, wake turbulence and weather avoidance.

Chairman UDALL. Dr. Shin?

Dr. SHIN. Well, I couldn't agree more with the other witnesses' areas that they are pointing out as the current NASA program clearly indicates that we do address those air traffic management, safety and environmental impact areas within the budget that is allocated by the President.

NASA AND NEXTGEN

Chairman UDALL. Let me move to NextGen, if I might, and I am not going to get all of these questions tied to NextGen in but we would have a couple of rounds.

Dr. Shin, speaking of NextGen, are you satisfied that the connection between the aeronautics R&D and the JPDO's research and development plan, integrated work plan is clear enough and is it a level of detail that allows NASA researchers to establish work priorities that will result in the timely delivery of NextGen's capabilities?

Dr. SHIN. I believe the JPDO has evolved significantly, both in terms of scope and quality of the documents they have been generated, and in particular last year all the member agencies worked very closely along with JPDO to generate several seminal planning documents. Because the nature of the work that JPDO is trying to embark and coordinate, it is a daunting task, trying to revolutionize the Nation's air transportation system, not just from air traffic management perspective but as I mentioned in my oral testimony, as a whole system. It is expected that such documents will take some time to have necessary depth and accuracy and clarity, so I think JPDO has been working diligently on that and NASA is heavily and very proactively participating in the development of all those documents.

Chairman UDALL. Thank you, Dr. Shin. I am going to return to this in the next round of questions but at this point I would like to recognize the Ranking Member, Mr. Feeney, for five minutes.

Mr. FEENEY. Thank you, Mr. Chairman. I also was interested in the progress of NextGen.

Mr. Meade, with respect to the seven areas where you discovered major deficiencies and the other 24 that have problems, which of those areas do you think are most critical that NASA can address within current budget and which do you think cannot be addressed with reform or changes without additional funding? Just identify some of the major ones. You said the priority would be NextGen and then safety and environment but can you be more specific?

Mr. MEADE. I could if I could refer to the study itself. There were 51 of those——

Mr. FEENEY. You have a complicated color chart here.

Mr. MEADE. As you might imagine, it was fairly complicated. Now, I would like to talk a little bit about the seven that we found major deficiencies. Four of those seven, NASA was not working on at all. I mean, those were simply omitted from the portfolio of research for various reasons, probably low priority or lack of staff or whatever. So that was—that applied to four of them. The other three——

Mr. FEENEY. For example, unmanned aerial vehicles.

Mr. MEADE. That is right, for example, and, you know, we could turn to that color chart that you have and see which ones are actually not worked on. There are three others that were poorly managed, probably best described as not advancing the state of the art for various reasons, and so we would recommend that those things with the current budget scenario be totally dropped or revamped, and to get to the basis of your question, though, Mr. Feeney, I don't think that we are in a position right now to tell you that this is the top priority and this is the second priority. As you know, the decadal survey itself refused to do that and listed the top 51 that they thought was the most important. I think what we would recommend as a committee, however, is that a priority scheme be established and have NASA itself go in and decide which is the most important ones to work on.

Mr. FEENEY. Well, they sort of do that every year when they propose their budget, I assume.

Mr. MEADE. They do, but so far we have not seen any evidence that they use the decadal survey as any sort of guiding light.

Mr. FEENEY. Mr. Meade, one of the recommendations was that NASA, and I quote, "not necessarily include the immediate public dissemination of results to potential foreign competitors." Mr. Henne, you know, listed three of his. I suspect there will be more in the future. Why did your group feel compelled to make this recommendation? Is it consistent with the practices of other Western governments when they do research and development? And then maybe we will hear from Mr. Henne and he may have an opinion on that as well.

Mr. MEADE. I think that comment was—the genesis of that comment began to build in our committee from looking back in the last 50 years of aviation history, particularly on the 1958 law that brought NASA into existence, where, as a matter of fact, Mr. Henne, in his testimony, quoted that one of the purposes of NASA was to make sure that America stayed in the forefront of aviation. Back then, there were natural inhibitors to the dissemination of information outside our borders and the feeling of the Committee was that this——

Mr. FEENEY. American cars and airplanes used to be made entirely in America back then too. That has changed.

Mr. MEADE. Used to be, right, and so we had a very large capability to absorb the fruits of the labor of all this research ahead of any competition. Well, Tom Friedman was right, the world is flat, and by the way, there are many competitors around the globe now that have just—can very quickly react to the results of that research and so we have to decide if the American public is paying for this very worthy research, that the American public gain the benefit of this research.

RESEARCH INFORMATION

Mr. FEENEY. Well, real quickly, you made a recommendation, if they find some quantum leap in capabilities, should they provide it to Mr. Henne's company that would affect, for example, just the niche that Mr. Henne is in. Should they provide it to Mr. Henne's company but no foreign companies?

Mr. MEADE. I think that is beyond the scope of what our committee would recommend. However, this is a competitive atmosphere that everybody operates in.

Mr. FEENEY. Mr. Henne, do you have an opinion about that?

Mr. HENNE. That is a difficult question. In terms of transfer of information, you certainly would like to think that information that is generated by research funded by the U.S. public advantages U.S. interests first. I mean, that would be a guiding principle. But in today's global environment where we have suppliers that are international, we deal with international sales, that dividing line gets pretty hard to define in reality and so you would like policies that advantage U.S. interests. If it becomes crippling, then it doesn't do anybody any good.

Mr. FEENEY. I will have some more questions if we get to a second round. Thank you, Mr. Chairman.

Chairman UDALL. The Chair recognizes the Chairman of the Subcommittee on Technology and Innovation, the Member from Oregon, Mr. Wu.

AVIATION AND THE ENVIRONMENT

Mr. WU. Thank you very much, Mr. Chairman.

Dr. Kroo, your testimony had some interesting comments about environmental effects of aviation and I wanted to focus on a particular environment effect which is not addressed in your testimony, and that is noise pollution. There is an interesting article in Aviation Week this week about helicopter rotor blades which make less noise. When I was either a freshman or sophomore, we no longer have the benefit of Mr. Weiner on this committee but he would ask very pointed questions about the next generation of jet engine technology that would be more quiet. It is my impression that whether it is from a research or more likely from a regulatory point of view, the Europeans have taken the lead in quieter engines. Are we putting enough research emphasis on noise pollution, in your view, and can you discuss that for us just a little bit?

Dr. KROO. Sure. There are two kinds of goals, one that may be addressed with regulatory issues, which are near-term goals, and then there are the goals that apply for a longer-term over the next couple of decades. Certainly some of the near-term goals can be addressed with regulation and in next generation designs of airplanes but in the future, rather dramatic changes in noise of aircraft are possible and are consistent with some of the other environmental goals so that as airplanes become more efficient, they don't just require more acoustic treatment on engines but the engines can actually be smaller. They can have less jet noise on takeoff and therefore airplanes designed with the environmental impact in mind can really be dramatically quieter.

Mr. WU. That is 20, 30 years out.

Dr. KROO. So the goal of the European framework research is to achieve half the noise by 2020, half the average noise. This is not inconsistent with some of the R&D aeronautics goals that have been provided quite recently in this country. That would make a dramatic difference. Having a lot more traffic would also make a dramatic difference, and we have to figure out how to accommodate that.

WIND TUNNELS

Mr. WU. Right, cutting the noise in half dramatically changes the noise footprint on the ground. Let me ask you a question about the research infrastructure. One of your colleagues at Stanford was very, very concerned a few years ago, I believe about the number of wind tunnels available for research here in the United States. In your view, has that situation gotten better or worse?

Dr. KROO. That situation is somewhat better. The Air Force, for example, has stepped up to fund some of the facilities in this country such as the national full-scale facility, the 80 by 120 foot wind tunnel located at NASA Ames. There are many wind tunnels that are continually closing down, being refurbished only not to be used in this country, and this is a difficult situation. We still go to Europe to do wind tunnel testing, and that is a problem.

Mr. WU. Mr. Henne, do you see going to Europe to use their wind tunnels as a problem?

Mr. HENNE. Let me—that is a fascinating question for me because we just completed a whole series of development wind tunnel tests on a new aircraft model, the last one being the most important, most expensive, and it was done in Europe.

Mr. WU. Do you see that as a problem?

Mr. HENNE. Yes, it is, because you have to believe, you have to walk out of that tunnel believing that your data is available to others.

Mr. WU. Dr. Kroo, would you agree with that assessment?

Dr. KROO. I think so. I do think that some of the facilities really are very good in Europe and we should take advantage of it but it is indeed always a question. I have to say with respect to keeping some of that data in the United States and with respect to the previous Member's question, it is a difficult question. One has to walk that line between——

Mr. WU. Dr. Kroo, I don't mean to cut you off but I am going to.

Dr. KROO. That is fine.

Mr. WU. Dr. Shin, how did NASA let the situation develop where Mr. Henne's data is going to be used by folks who didn't pay for it?

Dr. SHIN. To that very specific issue, NASA aeronautics has established a program called Aeronautics Test Program a few years ago and——

Mr. WU. But it doesn't seem to be working.

Dr. SHIN. Well, in the past, there has been some issues with the maintaining and up-keeping the NASA wind tunnels so that is why we established this program, and we are making good progress. We are also working with our partners in DOD so——

Mr. WU. So Dr. Shin, if we hold this hearing again in two years or in one year, will you have a different answer for Mr. Henne? Will you have a solution for Mr. Henne?

Dr. SHIN. We are certainly working toward that goal

Mr. WU. Are you working toward it or will you have a solution for Mr. Henne?

Dr. SHIN. We will do our best.

Mr. WU. Thank you.

NOISE AND AVIATION

Mr. HENNE. Mr. Congressman, I wonder if I could make a shot at the first question you asked, and that was about investment in noise. I don't believe that we, the United States, are investing enough in it and I brought two exhibits if you are interested. One is the CLEEN program, as provided—some information provided both by the FAA and NASA, and if you read it, it is a program proposed to spend up to $20 million a year for four, five years, up to $20 million a year for four or five years. This is at the same time that the announced program by the European Commission is $1.6 billion euro for seven years, which means $2.4 billion on the same subject, and so it is an order of magnitude larger investment in clean technology that is being made in Europe compared to the United States, an order of magnitude.

Mr. WU. I thank you for calling that to our attention.

I yield back, Mr. Chairman.

R&D AND NEXTGEN

Chairman UDALL. Thank you. We will start another round and the Chair recognizes himself for five minutes. I want to pick back up on NextGen and turn to Mr. Meade. In the area of advanced communication, navigation and surveillance, your committee found that NASA's aerospace efforts didn't have planned research to address their R&D milestones as identified in the recent decadal survey. Since the NextGen concept seems to rely extensively on those capabilities being available, should we be concerned?

Mr. MEADE. If I heard your question correctly, Mr. Chairman, I think we should be concerned. We evaluated the milestones against what we thought would be a rational program and found deficiencies in those sensor areas and so NextGen depends upon those sensors and the integration of those sensors within the aerospace systems and I would say that that would be a high-priority item.

NASA AERONAUTICS AND TECHNOLOGY DEMONSTRATION

Chairman UDALL. Does anybody else care to comment?

Let me move to Mr. Henne then. In your testimony, you state that NASA aeronautics needs to work beyond just fundamentals and needs to take a continuing role in technology demonstration, and then Dr. Kroo, you stated in your testimony that NASA has focused R&D activities on the kind of fundamental research that will be important for longer-term solutions. The next step is to understand how some of the most promising technologies can be integrated at the system level and transitioned form the lab to the user. It seems to me that both of you are saying that NASA needs to be more than fundamental or basic research if it is to be relevant to the Nation's needs. Is that correct?

Mr. HENNE. That is correct. Those two statements are very similar in reality. One of the things that seems to have dried up is large-scale demonstrations of technology. Those are the things that reduce the risk, that give companies confidence in fact that the technology is mature enough to take to market, and when that link is dropped because it is expensive, it costs a lot to do those kind of demonstrations, when that is dropped, you have broken the chain. The technology isn't going to advance. It is going to stay in the lab, it is going to stay in the office and it will be a small-scale study going on and on and on and progressing it to the market won't happen.

Chairman UDALL. Dr. Kroo, I see you nodding. Would you have an example as well of opportunities that might be missed——

Dr. KROO. Well, absolutely, and I think that it is often tempting to think of these as demonstrations but in fact they are also experiments. These kind of system-level research activities let you know what you don't know, and that is very important in this area.

Chairman UDALL. Mr. Meade, Dr. Shin, would you care to comment?

Mr. MEADE. I fully support it. One of the ideas that we came up with on the Committee was the fact that—or realizations, I should say, was the fact that there are very few flight experiments any longer for a couple of reasons. Everybody is afraid of failure, and once you get in the air, there is always a chance, particularly as you are advancing the state of the art, that it won't work, and that somehow is a negative mark on somebody's career and therefore there is a tendency to avoid those steps. And there is an intangible result from actually getting out into the field and flying something, and that is, you invigorate an entire generation of people who would like to come study in the avionics field, or I should say aeronautics field. So there is a tremendous benefit in making that user connection and also energizing the system.

Chairman UDALL. Dr. Shin, I would want to give you an opportunity to comment.

Dr. SHIN. Yes. I do recognize that we do not have large-scale technology demonstration or validation efforts, as Mr. Henne pointed out, so that is accurate statement, but I also like to submit that in current NASA aeronautics portfolio, we do sizable amount of flight experiments and working with industry and so those are not in the traditional sense large-scale, highly integrated flight validation efforts but we do work, as an example, blended wing body flight experiments that we are still conducting and also we, as a matter of fact, worked with Gulfstream on the sonic boom mitigation technology. That was done through flight experiments as well. So again, within the budget that has been allocated to us, we do believe we try to maintain the relevance with industry and also conducting flight experiments.

Chairman UDALL. I hear implied in your comments, though, if we were able to find more resources, there is certainly more than you could do in your directorate.

Dr. SHIN. I think we are—actually, NASA aeronautics and aeronautics community as a whole are in a good situation actually compared to previous years because we do have this national aeronautics R&D policy and plan that will guide us, government agency like NASA, to set the right priorities so we will continue to work within that plan and policy and make sure that our program is well aligned.

Chairman UDALL. Thank you, and the Chair recognizes the Ranking Member, Mr. Feeney, for five minutes.

Mr. FEENEY. Thank you.

NATIONAL RESEARCH COUNCIL ASSESSMENT OF NASA R&D ACTIVITIES

Dr. Shin, the National Research Council's assessment of NASA's aeronautics R&D recommended that, and I will quote, "The Aeronautics Research Mission Directorate should ensure that its research program substantially advances the state of the art and makes a significant difference in a time frame of interest to users." They go on to recommend that NASA, in consultation with the aeronautics research community and others as appropriate, should redefine the scope and priorities within the aeronautics research program to be consistent with available resources. So they essentially suggest that there needs to be some fundamental redefinitions of priorities and additionally, as Mr. Meade stated earlier, they suggested there may be a cultural problem with respect to the lack of urgency and a view towards who the end user is as opposed to NASA using the technology, the end user. How do you respond to the National Research Council's assessment and Mr. Meade's suggestion?

Dr. SHIN. I generally agree with the essence of the recommendation, which points out that NASA aeronautics should be staying relevant and sort of being up on the U.S. industry and U.S. aeronautics community, and for the past almost 19 years that I have been with NASA aeronautics, I have always thought, and my colleagues have always worked to address U.S. aeronautics community requirements and needs. So if there are some pockets of areas or groups of researchers who feel that NASA aeronautics is serving to our own need, that is something that I must correct and that is not what NASA aeronautics is all about. We don't produce our own aircraft or we don't serve to our own outcome. So again, in general, I respect NRC's observation and recommendation, so if there are cases like that, we will certainly work to remedy that.

In terms of staying relevant, we are making all efforts because we invite industry partners to our annual technical interchange meetings that all three research programs have, and so far we have had one or two of those such meetings since we restructured the aeronautics program, and I have gotten—and I have also participated in some of those meetings, have gotten a lot of healthy interactions, so tech transfer or knowledge transfer should happen at all levels, that is my belief, not just at the end of the rope when everything is culminated to some large-scale validation. So we have to work with industry partners and academia up front and all along the technology development so we actually identify the transition point jointly rather than NASA decides this is the point that we have to transfer the technology. So by doing some of these things and focusing on what we do best, NASA aeronautics does best, I believe we can make still significant contributions in staying relevant to U.S. needs.

Mr. FEENEY. You just mentioned your academic partners. Dr. Kroo is here. Also, you know, for example, adjacent to my district is Embry-Riddle University, which has a keen interest in aeronautics. What—can you describe NASA's cooperation and use of academic researchers? Because it appears to me that would be a place where cutting-edge, futuristic, you know, research is the norm, and if you want to stay not just current but ahead of the curve, academia seems to be, you know, an important part of that whole program.

Dr. SHIN. I wholeheartedly agree with your view toward academia's role in our nation, and to that end, two years ago we have set aside, not as an afterthought but we set aside $50 million out of our annual budget to bolster and promote and integrate these cutting-edge ideas and concepts coming from academia, and the funding vehicle is called NASA Research Announcement, in short, NRA. NRA is a very flexible procurement vehicle so it doesn't only allow grants, it could be cooperative agreements or contract even. The participants are not only universities but the idea of NRA is exactly what Mr. Feeney mentioned, to promote and bring out these cutting-edge ideas and concepts, and I am happy to report for about a year and a half that we started doing this, we have received over 1,300 proposals and we have awarded over 300 recipients through NRA process, and the market for the participants is growing and also spanning not just from academia and also industry. So today, again, I am happy to report that we have about 30 percent industry participation and 70 percent university in terms of number of awards, but in terms of funding, 40 percent industry and 60 percent academia. So one of the gratifying things through NRA that I have observed is some of these small universities or universities that we never really thought traditionally that they would have aeronautics expertise, we are getting a lot of these non-traditional engineering powerhouses, if you will, and a lot of good ideas and concepts. So it is solely based on the quality of the proposal and we are making good progress and I have been very pleased with the progress we have been making.

Chairman UDALL. I thank the gentleman.

I now would like to recognize one of the most active Members of this subcommittee, the gentleman from New Jersey, Mr. Rothman.

Mr. ROTHMAN. Thank you. I want to thank our distinguished Chairman and the Ranking Member for holding this very important hearing and for your consistent and strong interest in these matters, and I apologize for being late, gentlemen, I had another place to be, but I am very interested in this subject.

NOISE AND AIRCRAFT POLLUTION

Let me ask Mr. Meade—I have a few questions. I represent a densely populated region in the most densely populated state in the country. So aircraft noise and aircraft pollution are constant concerns for the quality of life of my constituents. I believe that aeronautics research and development creating quieter, safer, cleaner aircraft is an important aspect in dealing with the quality-of-life issues my constituents deal with on a daily basis. So Mr. Meade, what can this committee do to help NASA achieve these important goals?

Mr. MEADE. Well, I think as far as our committee, from the NRC is concerned, we would recommend that the decadal survey be followed with regard to the environmental challenges that they have already specified and so I think the best and shortest answer I can give you is, take a look at the decadal survey and direct NASA to adjust their priorities to respond to those challenges.

Mr. ROTHMAN. Thank you.

Dr. Shin, are you familiar with this survey that Mr. Meade has referred to?

Dr. SHIN. I am.

Mr. ROTHMAN. And has NASA taken into account the conclusions of that survey in its budget, in its project proposals or plans for the coming year?

Dr. SHIN. Yes. We have made a very thorough assessment from decadal survey, and in fact, we submitted our report to Congress a year and a half ago, as I recall. But in the environment area, this is one area that NASA aeronautics program actually has a very strong technology development effort.

Chairman UDALL. Dr. Shin, would you pull the microphone a little closer again?

Dr. SHIN. Yes. I keep doing that. For noise and emissions, these are the two areas actually we have a very strong portfolio in fundamental aeronautics program, and we have made a lot of progress in developing new concepts and also tools that will allow us to assess or develop new technologies.

U.S. R&D AND EUROPEAN R&D

Mr. ROTHMAN. Dr. Shin, if I may, because I only have a limited amount of time, I was present when Mr. Henne suggested that there was a large order of magnitude difference between our investment and the implication being our work in NASA in those areas as compared with Europe. Can you comment on whether there is this huge order of magnitude difference in either the quality of the work, the advancements achieved here in America versus in Europe?

Dr. SHIN. I think recently it is a well-known fact that the European community is trying to increase the commitment in their funding in aeronautics research and development. So as Mr. Henne accurately pointed out, the funding is growing there——

Mr. ROTHMAN. But in terms of the technology, you know, just to make a silly analogy, if they were still in the Stone Age playing with the wheel and figuring out what to do with that, they would need a lot more investment to catch up to where we are. Where are they, though, in technology with regards to reduction in aircraft noise and aircraft emissions relative to where we are in the United States, and are they going to pull ahead of us in some dramatic and unacceptable fashion because of the relatively smaller amount of research dollars that are included in the President's budget for our country?

Dr. SHIN. In short, my assessment is, we are still far ahead of the Europeans' capabilities and knowledge in addressing environmental impact. I do believe that. And Europeans have always copied, if you will, the goals and objectives that U.S. government agencies and also industry put out. So that is the one indication that Europeans are trying to catch up.

Mr. ROTHMAN. Mr. Chairman, do I have time for two more questions?

Mr. Henne, do you have a comment on that, Dr. Shin's last statement?

Mr. HENNE. I would say from our assessment of products coming from Europe versus products in the United States, they are very competitive. Our most recent engine selection was made selecting a Rolls Royce engine that is actually made in Germany, and it is an excellent engine, very low noise. They are extremely sensitive to low emissions. The engine company recently made an unsolicited change in the combustor to reduce emissions further, and we didn't even ask for it.

Mr. ROTHMAN. Dr. Shin, do you have any comment on Mr. Henne's last comment?

Dr. SHIN. Yes. I think the difference in my answer was, I was talking about R&D capabilities and I think Mr. Henne's answer was current product line. So that was the difference in my answer.

Mr. ROTHMAN. But in terms of the way people live practically, theoretical discussions of advancements in products are valuable but if they never reach the product line, they really—they won't help the quality of life as directly as those investments in product line research and development. When will we—when will this R&D

in aircraft emissions and other emissions from aircraft that is being conducted by NASA bear the fruit of better products if, as Mr. Henne says, the products are now equal?

Dr. SHIN. Your observation is valid, and the current U.S. technologies in noise and emissions reduction started from 10, 20, 30 years ago from NASA's research. So NASA's research has to put ourselves another 10, 20, 30 years ago ahead of current technologies and that is what we are doing.

AIR TRAFFIC CONTROLLERS AND NEXTGEN

Mr. ROTHMAN. One final question. I wanted to ask about, Dr. Shin, NASA's role in aeronautics research and development with regards to NextGen, and I will ask the question, if experts from the air traffic control community were consulted as this system has been developed, in other words, have actual air traffic controllers, the people in the towers who do this work every day, been involved in the development of this new air transportation system?

Dr. SHIN. I would like to—if I may, I would like to defer that question to actually FAA because air traffic controllers and that association is not part of NASA. My observation has been that JPDO and FAA have been working closely with air traffic controllers association and that workforce but I am not part of that agency so——

Mr. ROTHMAN. No, no, I didn't ask about that. Is your answer then that NASA has not involved the air traffic controllers in its research?

Dr. SHIN. We do heavily work with FAA and JPDO in air traffic management technology development.

Mr. ROTHMAN. I meant NASA directly with the air traffic controllers' expertise. Have you had that direct communication or do you rely on whatever FAA tells you their conversations with the air traffic controllers have informed them of?

Dr. SHIN. I apologize for not getting your question right away. We do work with air traffic controllers. In our research and development, we do use air traffic controllers as observers, also participants in developing our technologies, so we do have that close relationship, but in terms of actual working relationship within FAA, we don't . . . work that way.

Mr. ROTHMAN. Ten seconds. You have been so generous to me. I just want to make one comment to industry, that I do believe industry has——

Chairman UDALL. Mr. Rothman, why don't we do this? I will recognize the gentleman from Louisiana, Mr. Melancon, for five minutes and he can do whatever he would like with that time.

Mr. MELANCON. Mr. Chairman, I would like to yield my time to Mr. Rothman.

Mr. ROTHMAN. Oh, you are so kind. Thank you, Mr. Melancon. I just want to say, I don't take industry off the hook in terms of its responsibilities to do its own research and development and pay for it itself. They can't rely on the government to pay for it all, and while I respect and appreciate the profit motive and the great work and the great products made by private industry including great aircraft, you folks have some of that burden as well and you can't simply say the feds are not picking up the whole tab, so woe is us, so woe are us.

Thank you, Mr. Melancon, for yielding, and Mr. Chairman again for your generosity and your leadership as always.

Chairman UDALL. Thank you, Mr. Rothman. I would note that between the short time that Mr. Melancon yielded to you, the time you took that you had two- to five-minute blocks and you used them quite well, and I know I speak on behalf of your constituents who admire and respect the passion and intensity with which you bring to discussions of sound pollution and air pollution, and you have a very compelling case to make because when we get this right, not only your constituents but Americans all over the country will benefit for higher quality of life because this is a problem that concerns all of us. I hear about it in my district as well. I thank the gentleman from Louisiana for being so generous as well with his time.

Let me turn back to the panel. The Chairman recognizes himself for another five minutes.

NASA'S AVIATION SAFETY PROGRAM

Dr. Shin, I want to ask you what you consider to be the most promising areas of research at NASA's Aviation Safety Program that could lead to new capabilities being in sort of the marketplace in the next five years, even the next 10 years.

Dr. SHIN. Yes. As I mentioned in my testimony, we are enjoying the safest system, but we are also changing a lot of—we will be changing a lot of things in air traffic management system and also introducing new vehicle concepts. So when you mix all those things, you don't know what kind of new safety challenges will be ahead of us. So from a NASA research perspective, we are trying to be proactive and also forward looking utilizing the IT advancements in data mining and also analyzing and processing the data, so we are working with FAA closely to develop this aviation safety information and sharing system so automatically we can analyze the data and identify the precursors before the accident actually happens. So that is one such area that we are working on and also in projected highly automated system that we are all anticipating in NextGen vision, software validation and verification is very important, so we have to work proactively to develop technologies that can ensure that all the software and automation are functioning as designed, so validation and verification is another challenge.

Chairman UDALL. Anybody else on the panel care to comment?

Mr. HENNE. If I could, Mr. Chairman. Relative to safety, that is clearly a very high priority for our business, and I would like to point out one example of just excellent work by NASA that has led to a real-world improvement in aviation safety that is just now available, and that deals with synthetic vision. NASA has been doing synthetic vision work for years and years, and we some time ago did a joint program with NASA on a Gulfstream to look at synthetic vision. We flew it and learned things that were good, learned things that were bad. When we were done with that flight test experiment in conjunction with NASA work, we made a decision, it is time to go to market, let us take it to market. It has now been certified. It is now going out in our product line and it is a major advance in aircraft safety, and we are proud that NASA and we were joined together doing that to actually bring that to market in the end. So there is a lot of good things that NASA generates, they are the source of. The trick is to get that technology developed all the way and take it to market, and that is one just great example of aviation safety that is now done. It is available.

Chairman UDALL. Dr. Kroo, Mr. Meade, do you have any comments?

Dr. KROO. Just to look at the future area of aircraft safety, one of the academically interesting areas and an area that NASA is pursuing is the utilization of advances in autonomous systems and vehicle autonomy in general to both improve the safety of vehicles and to improve the situational awareness of pilots. That also creates difficulty if in fact there are autonomous vehicles operating in the same airspace. NASA is addressing that problem to some extent. There is a lot more needed.

NAOMS/ASIAS

Chairman UDALL. If I might, Dr. Shin, I would like to turn back to NASA's handling of the NAOMS aviation survey project, and as you all know, the Committee has been concerned. We have a GAO review underway to look at the survey data. I understand, however, that NASA and the FAA are working on another aviation safety database activity, and the acronym is ASIAS, I think *Ah-SI-uhs* is maybe how it is pronounced, and it involves significant data mining and the merging of multiple disparate databases. As you know, the Federal Government doesn't have a great track record on the development of such large database management systems. What are NASA and yourselves doing to ensure that this latest effort stays on track and on budget? Furthermore, what are the specific objectives, budget and timetable for the ASIAS project and how are the responsibilities divided between the FAA and NASA? You could respond for the record if you would like. I know I just threw a lot of questions at you.

Dr. SHIN. Yes. I just want to respond in real time about ASIAS, if I may, and the others I would like to provide more detailed information for the record, with your permission. In the ASIAS, I think the real positive aspect there, sir, is the participants and who are actually playing together in this ASIAS effort. It is not just NASA, it is not just FAA working in isolation. It is not just airlines holding their information. The beauty of this system is, airlines are voluntarily providing their operational data, safety data, and FAA is in the lead role to make sure that all the confidentiality and all the other considerations are protected so that airlines can share their data, and NASA is providing the necessary technologies so I go back to one of my earlier comments that the clearer each agency's roles are identified and understood, I think the better we will be off working together. So ASIAS is one such case that FAA is the primarily regulatory agency providing the protection and NASA is the R&D organization providing necessary technologies, and airlines do see the value so they are coming to work together.

Chairman UDALL. Let the record note that we say the acronym ASIAS, and if you all do the job you want to do, I think it won't be a common parlance. It will be an acronym that is only known to those who track these important efforts. I appreciate your explanation there, and if you want to add additional material for the record, the Committee would welcome it.

The Chair recognizes the gentleman from Florida, Mr. Feeney, for five minutes.

Mr. FEENEY. Well, thank you.

NATIONAL RESEARCH COUNCIL PRIORITIES/UAVS

Dr. Shin, the NRC assessment indicated, among other things, that there are about four areas that have been established as a priority by the decadal studies that are getting no attention whatsoever and no work is going on, and I wondered what the other three were and why they are not a priority but specifically with respect to the unmanned vehicles, it seems to me there would be some natural payoffs and that NASA would be the ideal place to study how we manage unmanned flight and how it relates to an increasingly crowded airspace. I know there are a number of federal agencies who have a keen interest in using unmanned vehicles, probably the private sector as well, and I wanted to know why, you know, what the reasons are that NASA has failed to establish a research project and make this a priority?

Dr. SHIN. Yes. I would like to suggest that NASA's current research portfolio does address UAV-related technologies. We do not have focus project bearing the UAV in the project name or title so one might think that we are not addressing UAV-related technologies, but if we examine all the portfolios that we have, technology investment, a lot of technologies are contributing to the UAV community that they need in the future. So again, from the R&D perspective, we are contributing to UAV requirements and needs. In fact, I have asked—this is a vague area because we don't have clear single project addressing UAV. I can certainly appreciate why external folks may feel that we are not addressing UAV as diligently or focused way as we should, so I have directed my program managers to come up with clear communication and cataloging all the things that the technology areas that are contributing to UAV, so that is in work, and when that documentation is completed, I would like to provide that to Congress for your information.

[The information follows:]

INFORMATION FOR THE RECORD

NASA expects to have the UAV documentation discussed above completed by the end of August 2008, and the Agency will provide to the Subcommittee the technology areas that the Aeronautics Research Mission Directorate is contributing to UAVs in that timeframe.

Mr. FEENEY. Well, thank you, and I can say that in addition to the technology, there is an issue about rules and protocols. The FAA for a long time hasn't really figured out how to manage UAVs, and that has been a hindrance, I think, in the private sector because they don't know when or if they are going to be able to get permission to fly, so to the extent that regulatory hurdles and technology hurdles are holding back some real opportunities where we know we have needs.

Mr. Meade, do you want to respond to Dr. Shin's——

Mr. MEADE. Yes, sir, I can. The UAV issues with respect to the decadal study, remember that we have to match up the milestones that are specified in the decadal study with what NASA is doing, and if there is not an exact match, well, then we basically have to say there is not a match, notwithstanding the fact that NASA is flying a couple of Global Hawks very recently, I do believe, and some other unmanned vehicles, and so they are active in that area to help explain a little bit of the confusion. They simply did not match up with the milestone specified in the decadal study, so that is where that comes from. Furthermore, with regard to the large systems analysis that would be required to integrate a UAV into the airspace and fly correctly, you know, NASA is very good at doing those sorts of things but they are not the regulatory agency for deciding how to fly them in the airspace.

Mr. FEENEY. And are you aware of the current status of the FAA's position as to giving permission or access to airspace for UAVs?

Mr. MEADE. From the Committee's standpoint, no. From my own personal opinion, the last I heard, it was get above the controlled airspace, which is 60,000 feet, and fly it out. Obviously that is a very specialized mission and that is—basically I am uninformed of any other operations.

Mr. FEENEY. But obviously that is having a real deterrent effect to development and use and experiments with UAVs.

Mr. MEADE. Absolutely. If you don't know what the regulations are going to be, you can't design your system correctly.

Mr. FEENEY. Okay. Thank you, Mr. Chairman.

Chairman UDALL. I want to thank the Ranking Member for his participation today, and I think this has been an excellent hearing. We have covered a lot of ground with a really focused set of questions and testimony. I want to thank all of you for your presence here today. I would editorialize that I think we have confirmed the importance of the aeronautics arm of NASA and I think we have confirmed the importance of it to our economy, particularly as we move forward. I think we have confirmed that we are in some strong competitive environments, Mr. Henne, but that we have the know-how and the capital and the potential if we have the right kind of support from NASA.

And this is where I will editorialize: I don't think we have enough resources. I look forward to working with Mr. Feeney during the rest of this Congress and with the next administration, whoever leads it, to find additional resources for the very, very important that is being done with NASA and in partnership with the private sector.

Mr. FEENEY. I wasn't going to say that I hope the next administrator is a former aviator, so I won't say that.

Chairman UDALL. There would be an element of leverage there, wouldn't there? But I hope whoever is the next President understands the importance of the new economy tied to aeronautics and, I would add, aerospace.

If there are no objections, the record will remain open for additional statements from the Members and for answers to any follow-up questions the Subcommittee may ask of the witnesses. We have already received a statement for the record from Mr. Costello, who also serves as the Chairman of the Transportation and Infrastructure Committee's Aviation Subcommittee. Without objection, so ordered.

This hearing is now adjourned.

[Whereupon, at 11:38 a.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Jaiwon Shin, Associate Administrator, Aeronautics Research Mission Directorate, National Aeronautics and Space Administration (NASA)

Questions submitted by Chairman Mark Udall

Q1. In its report, the National Research Council recommended that NASA establish a more direct link with the U.S. industry to provide technology transfer in a way that does not necessarily include the immediate, public dissemination of results to potential foreign competitors. This is consistent with the 1958 Space Act *establishing NASA which called for "the preservation of the United States preeminent position in aeronautics and space through research and technology development related to associated manufacturing processes." How will NASA implement NRC's recommendation?*

A1. There are several mechanisms in place to transfer knowledge between NASA and U.S. Industry. Specifically, non-reimbursable Space Act Agreements (SAA), NASA Research Announcement awards, and Small Business Innovative Research projects provide an opportunity to transfer knowledge. In addition, NASA personnel participating on technical committees (e.g., Radio Technical Commission for Aeronautics, Society of Automotive Engineers, American Institute of Aeronautics and Astronautics forums) inform those groups of latest research findings as they develop industry-wide standards, guidelines, and recommended practices for advance technology concepts. NASA Aeronautics Research projects also sponsor informal working groups with industry participation (many of whom are SAA partners) in which an open forum is provided for industry to learn the latest goings on in the project and for NASA to learn of emerging challenges facing the community.

NASA believes that publishing the results of its research is important to its mission. Part of NASA's charter in the *Space Act* includes the "widest practical and appropriate dissemination of information." The National Aeronautics R&D Policy also directs NASA to "provide for the widest practical and appropriate dissemination of research results, consistent with national security, foreign policy, and the Office of Management and Budget's Information Quality Guidelines." In addition, many of NASA's research areas (for example air traffic management research) must be coordinated with other research and regulatory entities around the globe, given the global nature of air transportation.

Q2. The NRC found that NASA's four research centers focused on aeronautics, which account for less than one third of NASA's total civil service workforce, absorbed almost 80 percent of NASA's reduction in civil service employees. Are there plans to continue this trend or redress this imbalance in the next five years?

A2. Achieving success and sustaining vibrancy in all of NASA's mission areas over the next few years is a challenge requiring NASA to draw on all of its expertise and resources. Mission success will depend on ten strong, healthy Centers, and the Agency is committed to workforce management that supports that goal. Workforce planning has been more effectively integrated into the annual budget process and the assignment of work to the NASA workforce is supported through a high level of collaboration between the programs and the Centers. Where civil service work demand exceeds available workforce at a Center, it is shifted to Centers where workforce is available. With plans to assign important space flight development activities in exploration and science to all of the Centers, NASA does not expect significant declines at three of the four research Centers. The exception is the Dryden Flight Research Center (DFRC), for which an estimated 6.2 percent reduction is anticipated in the civil service workforce from FY 2007 levels to the estimated FY 2013 levels. However, with significant work assignments remaining to be made in support of various exploration programs, NASA is committed to finding a viable, long-term role for DFRC.

Q3. The absence of runway incursion tools is one of the most glaring omissions in today's air transportation system. What can NASA do to assist Federal Aviation Administration (FAA) in correcting this deficiency and improve the safety of airport runways?

A3. NASA has been instrumental in developing technologies that can: sense where aircraft are on the airport; portray where the aircraft are to the pilot; portray Air Traffic Control (ATC) clearances to the pilot; and, alert the pilot if he/she deviates from their assigned flight path, or if a hazardous runway incursion has occurred. This research complements Federal Aviation Administration (FAA) research, which has largely focused on technologies to aid the controller and on airport signage, lighting, and markings. Runway safety is one of the FAA's highest priorities, as evidenced in their major investments in Airport Surface Detection Equipment-Model X and Runway Status Lights, and the Runway Incursion Reduction Program. The benefits of NASA's developments have been published, and NASA personnel continue to serve on Radio Technical Commission for Aeronautics standards committees to communicate their findings to industry. The current and planned future NASA research and development related to runway incursions extends the previous work by focusing on the implications of NextGen operating concepts.

On an ongoing basis, NASA can assist the FAA in several ways: provide technical advice support the FAA in advancing and expediting the implementation of enabling technologies in system concept as defined by the past FAA/NASA collaborative efforts; participate in standards development activities; provide human factors subject matter expertise to review of FAA-developed mitigations; and continue to participate in runway safety forums organized by FAA.

Q4. How important is NASA's human factors research to NextGen? What human factors research is NASA planning to do to validate NextGen's ability to shift decision-making from the ground to the cockpit?

A4. NASA understands the importance of human systems integration creating an effective and efficient NextGen air transportation system, and has planned critical Human System Integration research in its programs. The Airspace Systems and the Aviation Safety Programs research the evolving role of humans in a more highly automated national airspace system. Defining the roles and responsibilities between pilot and controller and between human and automation is an active area of research in both programs. In addition, understanding issues involved in assigning the locus of control, whether it be on the ground (a centralized control concept) or on the flight deck (a distributed control concept), will be critical to full development of an efficient concept of operations for NextGen. Research to answer these fundamental questions is currently being pursued in early stages of operational concept development and by conducting human-in-the-loop evaluation studies employing active controllers and pilots. Human System Integration research is important to the advances in areas of separation assurance, dynamic airspace configuration, flight deck situational awareness, and airspace super-density operation.

Q5. The Secretary of Transportation tasked the JDPO with developing an action plan with its partner agencies that would accelerate the introduction of NextGen capabilities, possibly with a regional demonstration. What, if any, would NASA's role be?

A5. NASA will continue to address the fundamental research needs for NextGen by conducting applied research and development for advanced vehicles, safety and air transportation systems. Fundamental research includes foundational physics, discipline and multi-discipline studies and system-level integration. The Fundamental Aeronautics, Aviation Safety and Airspace Systems Programs conduct this research.

Under the NextGen Acceleration Action Plan, the Federal Aviation Administration (FAA) will implement several algorithms that were completed by NASA under the Airspace Systems Program. These algorithms include aircraft sequencing and scheduling under airport constraints and surface management. Because the research is complete and the algorithms have already transitioned to the FAA, NASA will have at most a limited consulting role for implementation.

NASA's direct contribution to the Action Plan is to accelerate validation studies that are coordinated with the FAA and the Joint Planning and Development Office (JPDO) via Research Transition Teams. In particular, NASA will accelerate validation and demonstration of methods related to traffic management advisor and surface management. The NASA and FAA Research Transition Team co-leads have been identified for both surface and traffic management, and planning workshops are underway to establish joint roadmaps. In addition, NASA will collaborate with the FAA to insure that research studies focus on regions, such as south Florida, that are targeted for FAA demonstration and implementation. NASA's contribution, which is consistent with our long-term research role, will enable the FAA to increase the impact on air transportation system capacity of the initial deployments as expanded capabilities are proven.

Lastly, the FAA has expressed an interest in accelerating the implementation of technologies for closely spaced parallel runways. NASA is reviewing its portfolio in super density operations to determine if planned studies address the FAA's concept exploration requirements for closely spaced parallel runways.

Q6. In identifying research challenges in NextGen, you cite in your statement the need for "improved software verification and validation techniques to prevent anomalies that could propagate across highly integrated systems with unintended consequences." With the difficulty both the Federal Government and the private sector experience in competing for software engineering talent, what strategies will NASA use to address this issue in a comprehensive way?

A6. NASA's Aviation Safety Program has two approaches for addressing this issue. First, the Integrated Resilient Aircraft Control project is developing methods of verifying and validating complex flight software. Second, the Integrated Vehicle Health Management project is examining methods of software health management (i.e., on-board monitors that can identify anomalies in software-driven behavior before they propagate). NASA's in-house level of effort is relatively small but is being given additional resources to grow. NASA also is discussing collaborative research with the National Science Foundation, and has issued several NASA Research Announcements and Small Business Innovation Research to involve industry and academia and extend the scale of our research.

Q7. What will be the state of NASA's research in an on-board system to detect hazardous icing conditions when it is completed? Would this include validation and operational demonstrations? What do you plan to hand over to the private sector?

A7. A wide range of icing research is central to NASA's Aviation Safety Program. Within this program, the Intelligent Integrated Flight Deck project is developing a range of look-ahead technologies to portray potential icing conditions to pilots before they enter them. The technologies, utilizing radiometry and radar, determine the threat severity and will communicate to the flight deck through the on-board External Hazards Monitor. The Integrated Vehicle Health Management project is developing sensors to identify ice accretion on the airframe and in the engine, allowing pilots to take corrective action before the accretion becomes severe. The Intelligent Research Aircraft Control project is examining the underlying physics of ice accretion in jet engines with the goal of developing propulsion systems that are not susceptible to icing. This work includes validation in the Icing Research Tunnel and other ground-based facilities, and flight validation on NASA's specially instrumented Twin Otter and S–3 Viking. NASA is widely recognized as a world leader in the field of aircraft icing. NASA collaborates extensively with the Federal Aviation Administration and with the private sector (including through reimbursable work sponsored by industry, and through Space Act Agreements, NASA Research Announcements and Small Business Innovation Research; hence transfer of the technology is natural. NASA personnel also actively contribute to a range of industry working groups and standards committees to examine further needs for NASA research to enable successful transition of these technologies to the private sector. NASA technical publications will also be used.

Q8. What is the current understanding of the effects of space radiation and solar x-ray events on aircrew and on aircraft systems including avionics, high frequency communication, and GPS navigation systems, especially during high latitude polar routes? What specific issues are not well understood and what, if any, research is being conducted by NASA to address those gaps? What, if any, interaction does NASA's Aeronautics Research Mission Directorate have with NASA's Science Mission Directorate, the JPDO, and agencies such as National Oceanic and Atmospheric Administration (NOAA) on the status of research, models, and data from satellite sensors that may help improve the prediction and severity of space weather events and their potential application to civil aviation?

A8. NASA's Aviation Safety Program has examined, and continues to examine, the impact of high intensity radio frequencies and other strong sources of radiation, including lightning. NASA's Aeronautics Research Mission Directorate (ARMD) is not conducting research on the effects of space radiation and solar x-ray events on either air crew or aircraft systems; however, NASA's Science Mission Directorate actively conducts research on space radiation and solar x-ray input into Earth's geospace environment and co-chairs the interagency National Space Weather Program. The Science Mission Directorate is the lead NASA representative on the JPDO Weather Working Group whose goal is to reduce the adverse impacts of weather on air traffic operations. Space weather events and their potential application to civil aviation fall within the scope of the Weather Working Group, and long-range plans envision space weather data to be incorporated within the net-centric four-dimensional weather information system. ARMD participates on the Weather Working Group. Further, ARMD also represents NASA on the NextGen Executive

Weather Panel that includes senior executives from the Federal Aviation Administration, NOAA and Department of Defense.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Carl J. Meade, Co-Chair, Committee for the Assessment of NASA's Aeronautics Research Program, National Research Council

Questions submitted by Chairman Mark Udall

Q1. Mr. Henne recommended in his testimony that NASA's Aeronautics procurement policies be enhanced to allow commercial contracting practices. During your review of NASA's aeronautics program, were contracting difficulties identified by the Principal Investigators the Committee met with? In your opinion, would the use of commercial contracting policies, as advocated by Mr. Henne, alleviate these difficulties?

A1. No Principal Investigator (PI) mentioned difficulties with contracting as an impediment to their research. I suspect, however, that such comments would have been thought to be outside the scope of the Committee's interests and therefore considered irrelevant by the PIs. It is commonly recognized that the government procurement practices are structured to be (and be perceived as being) fair and impartial—at the price of efficiency. Although the government has made some strides to reduce the bureaucracy associated with "small" procurements, my experience shows that there remains a significant difference in the efficiency between and commercial procurement practices. Although it is vitally important that the system be structured to eliminate any potential for abuse, there is a point of diminishing returns where the effort expended to make a perfect system is much more costly than one that is agile, flexible and adaptable to the immediate situation.

Q2. With regards to NASA's research facilities, your committee found that these facilities, with a few exceptions, meet the relevant needs of existing aeronautics research. However, your committee also noted that at the current investment rate, widespread facility degradation will impact the ability of ARMD projects and other important national aeronautics research and development to achieve their goals. Consequently, your committee recommended, absent an infusion of additional funds, that NASA continue to assess facilities and mothball or decommission facilities of lesser importance so that the most important facilities can be properly sustained. How serious do you view the future state of NASA's research facilities? How should your recommendation on possibly moth-balling or decommissioning facilities be considered by the RDT&E infrastructure plan currently being developed in response to the 2005 NASA Authorization Act?

A2. The Committee considers the current status of NASA aeronautics research facilities, as 'minimal.' We endorse NASA's efforts to ensure that retention/maintenance of facilities carefully aligned with the research objectives. Furthermore, the requirement to maintain NASA research infrastructure should be evaluated while considering both DOD and NASA facilities to eliminate overlap and duplication, if any. To this end, the NASA Administrator and the have established the National Partnership for Aeronautical Test (NPAT) alliance. As a result, two studies of NASA and DOD facilities has been chartered. The first study was of Transonic Wind Tunnels and was completed in October 2007 (documented in AEDC–TR–07–12.) The second study is underway and is investigating Supersonic Wind Tunnels. Additional studies are planned for Subsonic Wind Tunnels and Hypersonic Wind Tunnels. These studies will gather detailed information on the government facilities of interest to compare capabilities/conditions of the facilities. These studies, in addition to the NSTC's "National Plan for Aeronautics Research and Development and Related Infrastructure," could be used to determine the national RDT&E infrastructure that satisfies national aeronautics R&D goals and objectives. This will drive assessments of which facilities should be maintained, upgraded, moth-balled or decommissioned. Nevertheless, even with the optimum investment of funds currently budgeted for NASA's aeronautics facilities, as time passes it is more and more likely that facility shortcomings will become a serious impediment to aeronautics research by NASA and the Nation and/or increase the extent to which U.S. aeronautics R&D programs must rely on foreign facilities.

Q3. In correlating the 51 highest-priority R&T challenges in the Decadal Survey of Civil Aeronautics *to NASA's research portfolio, your committee found that over a third reflected inconsistencies between NASA projects and the Decadal Survey. Can you give us an example of an area of inconsistency, particularly one resulting from NASA choosing to do little or no work? Was the reason related to inadequate funding or something else?*

A3. The Committee found that inconsistencies are generally the result of NASA choosing to do little or no work in a particular task area and/or selecting research goals that fall short of advancing the state of the art far enough and with enough urgency either to make a substantial difference in meeting individual R&T challenges or the larger goal of achieving the strategic objectives of the *Decadal Survey of Civil Aeronautics.* Examples of inconsistencies can be seen by examining Decadal Survey challenges such as D10 (Safe Operation of Unmanned Air Vehicles in the National Airspace,) and B3 (Intelligent Engines and Mechanical Power Systems Capable of Self-Diagnosis and Reconfiguration Between Shop Visits.) Considering D10; neither the NGATS ATM–Airportal Project, NGATS ATM–Airspace Project, nor the IRAC Project have planned research to address the Decadal Survey milestones. Considering B3; although the Subsonic Fixed Wing and Supersonic Projects are participating in this research area, their results are unlikely to make a significant difference to the state-of-the-art; most of the research relevant to this challenge for these flight regimes is being funded by organizations other than NASA.

However, as noted in the Committee's report, NASA does not have the resources necessary to address all 51 R&T challenges simultaneously in a thorough and comprehensive manner, and so it is inevitable that the project plans, as a whole, do not fully address all the priorities of the Decadal Survey. Determining how or why ARMD decided which priorities to pursue—and which to defer—was beyond the scope of our study, and the Committee was not given adequate information to this issue.

Questions submitted by Representative Tom Feeney

Q1. During your appearance before our subcommittee, you testified that aside from the quality of the research conducted by ARMD, we would stress the need for a cultural change within the directorate. Indeed, the Committee was most concerned about the lack of urgency demonstrated by some projects and the tendency of some researchers to assume that the ultimate consumer of the fruits of their labor was NASA itself. You then went on to cite one of ARMD's guiding principles as an example of, perhaps, poor guidance that might drive this mindset. Could you elaborate further on the need for cultural change? Beyond the lack of urgency mentioned in your statement, what other attributes did the Committee find deserving of attention?

A1. The Committee came to recognize that some (but certainly, not all) PIs exhibited an inwardly focused attitude. We noted also the three guiding principles published by ARMD:

1. We will dedicate ourselves to the mastery and intellectual stewardship of the core competencies of aeronautics for the Nation in all flight regimes.
2. We will focus our research in areas that are appropriate to NASA's unique capabilities.
3. We will directly address the fundamental research needs of the Next Generation Air Transportation System (NextGen) in partnership with the member agencies of the Joint Planning and Development Office (JPDO).

Considering the above principles—particularly the first two—it may not be surprising that several contact with other stakeholders and have evidently failed to benchmark their objectives and progress against external research(ers). Consequently, the Committee recommends that NASA focus on ensuring better ties between its research and the intended users of its research. Specifically, ARMD should ensure that its research program substantively advances the state of the art and makes a significant difference in a time frame of interest to users of the research results by (1) making a concerted effort to identify the potential users of ongoing research and how that research relates to their needs and (2) prioritizing potential research opportunities according to an accepted set of metrics. Furthermore, ARMD should bridge the gap between research and application—and thereby increase the likelihood that this research will be of value to the intended users—as follows:

- Foster closer connections between NASA principal investigators and the potential external and internal users of their research, which include U.S. industry, the Federal Aviation Administration, the Department of Defense, academia, and the NASA space exploration program.
- Improve research planning to ensure that the results are likely to be available in time to meet the future needs of the Nation. Consistently articulate during the course of project planning and execution how research results are tied to capability improvements and how results will be transferred to users.

Implementing the above actions will require the flexibility to assign personnel possessing the right scientific talent to the right job at the right time. The current personnel practices of the NASA Centers inhibit flexibility. The inability to reassign personnel with ease as the situation dictates will inevitably result in organizational behavior that matches its goals to the personnel on hand, rather than the preferable alternative: choosing the most worthwhile goals and then staffing with the correct personnel to achieve those goals.

Q2. Assuming that ARMD's budget profile does not change substantially in the near-term, given a choice between continuing its current approach of foundational research across a broad swath of research topics versus funding periodic large-scale demonstration flights at the expense of limiting research to a smaller set of projects and activities, which option would you find more attractive, and why?

A2. In the short-term, a narrowly scoped ARMD research program that includes flight demonstration projects will be most valuable. However, reducing the scope of NASA's research will cause long-term harm by eliminating the basic research that would provide the foundation for applied research in the future. The "best" approach is a matter of philosophy and expectation. If one expects the ARMD budget to one day be restored to historic levels (allowing NASA to conduct meaningful research on a wide variety of aeronautical disciplines and applications) then it makes sense for NASA to continue a broadly-scoped program of foundational research. This would conserve core competencies until that brighter day arrives, even though it means that NASA would be unlikely to make significant contributions to solving the critical aeronautics issues of today. On the other hand, if one believes that the current retrenchment in the NASA aeronautics budget is likely to continue indefinitely, then NASA would be better served by making the hard choices to reduce the scope of its research and focus its resources on areas where it can make significant contributions. Regardless of the approach taken, the Committee emphasizes that all aeronautics research must eventually be validated in flight. Government flight demonstration are important because in many cases flight demonstrations are beyond the economic viability of the commercial sector. This is particularly true with breakthrough technologies that have the highest potential payoff—and the highest risk of failure. Re-establishing major flight demonstration projects under NASA sponsorship has the added benefit of encouraging and inspiring our young people to consider a career in aerospace engineering.

Q3. During the hearing, it was suggested that ARMD research findings initially not be broadly disseminated in order to provide domestic companies an opportunity to capitalize on new discoveries. Do you agree with this concept?

a. If such a policy were implemented, what effects would it have on domestic companies' ability to do business with foreign partners and customers? Would it imperil business relationships and collaborations?

b. How does NASA's current policy compare with that of other foreign governments who underwrite aeronautics research and development? Do they publicly disseminate new discoveries?

A3. It is essential to understand the very limited nature of the recommendation that the Committee is making with regard to foreign dissemination of research results. In particular, I agree with the Senior Vice President Henne's statement during the hearing, that if NASA policy regarding the dissemination of research results "becomes crippling, it doesn't do anyone any good." However, the U.S. aerospace industry competes on an international scale. In the Internet world of today, when research results are made public, they are available instantaneously to domestic and foreign competitors alike. Foreign competitors are often more agile (due to various reasons such as less burdensome regulatory environment, etc.) and can react more quickly to incorporate research results into marketable products. The Committee recommends that NASA establish a process that would allow the American taxpayer, as underwriters of NASA research, to have an opportunity to benefit from the research products before making them available for off-shore production. recommendation would provide additional inducements for industry and academia to partner with NASA, without creating any new requirements that would discourage such partnering. In particular, the Committee recommends that NASA establish a mechanism U.S. commercial sector researchers could use, at their sole discretion, to limit the dissemination of research they conduct with NASA. Such a mechanism would not inhibit academic researchers, who generally want to publish the results of their research and who are staffed with many foreign nationals. Neither would it inhibit industry researchers from publicly disseminating the results of their research when they believe it is beneficial to do so. But if a U.S. company and NASA would benefit from cooperative research with NASA, having the option to limit dissemination of its research results to foreign competitors for a period of time might make that company more inclined to partner with NASA in that research, to the benefit of NASA, the U.S. aeronautics industry and the public in general. Framed in this way, such a policy would not inhibit a domestic company's ability to do business with foreign partners and competitors since the limitation on public/foreign dissemination could be waived at the discretion of the U.S. company conducting the research.

The Committee did not investigate the policies of any foreign governments. Although I do not know the details, it is my belief that most foreign governments restrict the world-wide dissemination of their aeronautics research.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Preston A. Henne, Senior Vice President, Programs, Engineering and Testing, Gulfstream Aerospace Corporation

Questions submitted by Chairman Mark Udall

Q1. In your statement, you indicate that financially successful and environmentally acceptable civil supersonic transportation is still to be achieved. What are the challenges associated with civil supersonic transportation and what role should NASA's R&D play in addressing them?

A1. The challenges are many, but environmentally acceptable implementation is essential to financial success. This requires mitigation of the sonic boom which we all know significantly hampered Concorde operations, as well as adaptability to new engine technologies which reduce harmful emissions. A research aircraft must be developed and flown over land to demonstrate the sonic boom mitigation technologies, and through that, provide the technical database for justifying a change in current supersonic flight regulations.

NASA, in partnership with industry, has the enterprise to engage such a plan for our country, and prove out the resultant capability through a large-scale, "relevant," low-boom flight research program. This program would provide both a focal point and transition opportunity for various NASA R&D pipelines and conclude with an exploration of community response to low-boom, supersonic flight over land.

Q2. I understand that Gulfstream Aerospace and NASA have had a successful partnership in testing the Quiet Spike™ concept in flight, an extendable telescopic boom that helps suppress sonic booms. How well did that research collaboration work? Are there any "lessons learned" that you think should be applied to NASA's interactions with industry in the future?

A2. It worked very well. The Gulfstream team provided the idea and the hardware, and NASA provided the flight test platform and flight test expertise. Gulfstream and NASA concluded the Quiet Spike™ flight test program with an extremely successful industry-government partnership. It was not without its share of challenges. In the end, the success came from a small, experienced, and highly-motivated team being fully integrated into NASA's research environment with frequent open communication and an aggressive technical goal.

Q3. At present, commercial supersonic flight over the U.S. is prohibited due to sonic boom concerns. What needs to happen for that prohibition to be removed, and what role should NASA play? Are there other research areas related to commercial supersonic flight that NASA should be involved in?

A3. The prohibition needs to be converted to a rational rule that manufacturers can use for design and to show compliance with. This regulatory change needs to occur in the ICAO/CAEP international environment for setting accepted international standards. This process, while started, is in need of real flight data indicating feasibility. As stated above, flight demonstration of a low-boom aircraft that achieves an "acceptable" acoustic signature at the ground would greatly facilitate removal of the supersonic prohibition and establishment of a new standard. The flight vehicle proves the physics and validates that shaping technologies eliminate the environmental and social acceptability concerns associated with the sonic boom.

Ideally, NASA would fully fund such a program. However, a more financially practical approach for NASA would be to engage in a supportive and collaborative effort with industry in the development and test of the experimental low-boom vehicle. NASA can also be involved at a more detailed level sharing its expertise and resources with industry partners in research areas such as propulsion, aircraft structure, flight controls, aerodynamic modeling to name only a few. In parallel, NASA should also be tasked with preparing for flight research by developing and demonstrating a capability for monitoring community response using telemetry and instrumentation to correlate what's being heard with Internet-based social surveys that enable broad data collection and analysis.

Q4. In your statement, you recommend that NASA Aeronautics procurement policies be enhanced to allow commercial contracting practices. Can you provide some more details on what you see as the problem and why the use of commercial contracting practices might be an answer at NASA?

A4. Traditional NASA contracting imposes restrictive government cost accounting standards under FAR Part 15. This requirement is non-typical for commercial entities such as Gulfstream and discourages partnerships. In addition, restrictive data rights clauses further deter participation in research efforts for fear of losing competitive advantage and key intellectual property necessary for market transition.

In contrast to restrictive cost accounting, FAR Part 12 includes existing commercial terms which can provide NASA with adequate contractual protection under research contracts. Also, less restrictive data rights provisions would likely encourage otherwise reluctant commercial firms to support NASA technology development programs. The allowance or provision for these established commercial policies could substantially increase the pool of capable R&D resources NASA has available to support its programs.

Questions submitted by Representative Tom Feeney

Q1. Assuming that ARMD's budget profile doesn't not change substantially in the near-term, given a choice between continuing its current approach of foundational research across a broad swath of research topics versus funding periodic large-scale demonstration flights at the expense of limiting research to a smaller set of projects and activities, which option would you find more attractive, and why?

A1. The latter option is more attractive and is a critical mechanism for NASA to fully realize its Aeronautics mission. Periodic large-scale demonstration by NASA Aeronautics has a proven record for lowering technology risk to a level where industry is able to assist with the completion of the maturation process. When properly planned for and executed, large-scale demonstrations result in flying laboratories of exceptional value, national facilities that can provide tremendous research capability extending far beyond the initial test mission and period of performance.

Q2. During the hearing, it was suggested that ARMD research findings initially not be broadly disseminated in order to provide domestic companies an opportunity to capitalize on new discoveries. Do you agree with this concept?

a. If such a policy were implemented, what effects would it have on domestic companies' ability to do business with foreign partners and customers? Would it imperil business relationships and collaborations?

b. How does NASA's current policy compare with that of other foreign governments who underwrite aeronautics research and development? Do they publicly disseminate new discoveries?

A2. We agree in concept, that U.S. Government funded research should benefit domestic companies. This is consistent with NASA's original charter. Various NASA programs in the past have had levels of restricted dissemination depending on the program.

If such a dissemination policy were implemented, we do not believe there would have to be a negative impact on the aeronautics industry's ability to work with foreign entities—partners, suppliers and/or customers. Meaningful collaboration could still occur, however, U.S. industry would clearly be in a stronger position, given knowledge of government supported technology research activities. The policy will likely need to include an approval process to disclose based upon commercial potential for the U.S.-based entity.

Foreign governments often restrict the publication of new discoveries developed with government funding. While the practice varies considerably, foreign governments appreciate the value of the aeronautical enterprise and their investment in it. They do introduce protective measures to benefit their national interests.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ilan Kroo, Professor, Department of Aeronautics and Astronautics, Stanford University

Questions submitted by Chairman Mark Udall

Q1. You note in your prepared statement that the anticipated growth in air travel is a tremendous challenge, made even more difficult and complex by the insertion of potentially larger numbers of unmanned aircraft and even supersonic aircraft. How does the inclusion of unmanned and supersonic aircraft in the national airspace impact on safety? What research is needed to properly account for the future assimilation of disparate aircraft flying at different regimes in the national airspace? Is NASA doing or planning to do that?

A1. At the moment, unmanned and supersonic aircraft are not significant issues affecting the capacity or safety of the airspace system. But we anticipate that with additional applications for more-autonomous aircraft in the future and with the possibility of small civil supersonic aircraft, the wide speed and altitude range of this diverse set of air vehicles could become problematic—especially with our current approach to air traffic management. Rather than stifling innovation in this country by banning new types of flight vehicles, research is needed on how such aircraft may be accommodated in a next generation air traffic system. NASA is doing some research in this area as part of the aeronautics program and through the JPDO, but more extensive cooperative work with DOD and FAA needs to be undertaken, particularly for improved autonomous sense-and-avoid capabilities and more flexible, adaptive approaches to air traffic scheduling and control.

Q2. I note that you have spent some time in NASA as a researcher. Granted this was 20 years ago, but can you provide your views on how the in-house researcher role has changed over the years? In particular, do you agree with the concern expressed in the recent NRC report assessing NASA's aeronautics program regarding research time being taken away from in-house NASA personnel to monitor the performance of outside entities?

A2. Despite NASA's declining budget for aeronautics over the past decade, the Agency still manages to contribute in an important way to research advances in aeronautics. The role of NASA researchers has indeed changed greatly over the past twenty years, mostly due to three factors:

a. Changes in the way in which facilities are charged and closing of many smaller experimental facilities makes it much more difficult for researchers to use these facilities themselves. When I was a researcher at NASA's Ames Research Center, we tested several new, in-house designs in the wind tunnels at Ames. This happens very infrequently now as the larger projects and industry pay for the facilities and NASA researchers support those tests.

b. There has been a rather inconsistent relationship with industry and academia over the past twenty years. In the 1990's many of NASA's aeronautics projects were associated with a smaller number of large industry programs, while an emphasis on more fundamental work over the past two to three years has allowed universities and small companies to play a greater role. As a result, NASA researchers' involvement in externally funded research has changed and it will surely take some time to adapt to these changes.

c. The decrease in the number of experienced, aeronautics-oriented, civil servants at NASA does mean that a larger fraction of these peoples' time is spent monitoring the external research funded by NASA. Although the total amount of external research funding has not changed dramatically in ARMD, the larger number of smaller contracts and the shrinking internal research budget and staff does place increased demands on researchers' time, especially in some of the project areas.

Q3. In characterizing the need to address the environmental problems facing aviation, you state that while NASA's fundamental research work addresses some of the issues, the work needs to be expanded and focused on the most promising technologies if it is to contribute in a significant way to solving these problems. Could you please elaborate a bit on that statement—what technologies do you think are worth focusing on, and how should NASA proceed? Because of the uncertainty associated with how aviation emissions will be dealt with worldwide, how would you respond to the concern that we may be honing in on solutions without a clear idea of the problem?

A3. NASA has recently adopted some challenging environmental goals for future aircraft, and these may help to provide a focus for fundamental research in various fields of aeronautics. However, a large array of technologies may be said to contribute in some way to these goals and a clear approach to prioritization is needed. The NRC *Decadal Survey of Civil Aeronautics* identified a large number of technologies that will likely be important in the development of future aircraft with more stringent environmental constraints, but it did not make specific recommendations regarding prioritization in light of the budgetary constraints under which NASA is operating. NASA seems to be doing a good job of identifying some of the most promising research over the last couple of years, but the problem is great and the scope of NASA's aeronautics research is very limited.

Although many aspects of aircraft emissions' impact on the global environment remain uncertain, and the international community's approach to regulation or economic incentives is not completely formulated, many of the technologies important for future aircraft are not so uncertain. The benefits of improved fuel efficiency include, not just lower CO_2 emissions, but reduced fuel cost, greater independence from foreign suppliers, and improved performance for both civil and military aircraft. It is important to better understand the relationship between aircraft emissions at altitude and atmospheric changes, but there is little chance that research enabling reduced noise and greater efficiency will be honing in on the wrong solution.

Q4. In your opinion, is NASA's research on environmental issues too focused on NextGen or is it broad enough to address the issues that are percolating globally?

A4. NextGen as broadly defined, covers almost any aspect of a next generation air transportation system. However, as NASA's work on NextGen proceeds, areas of emphasis must be identified and it appears that air traffic control/capacity expansion will likely form the heart of NASA work on NextGen. This is certainly an important research area because near-term changes to ATC are needed to maintain safety, while permitting future capacity increases. But it is important not to assume that the development of new and efficient ATC system will solve the problems of a next generation aviation system. Appending environmental and efficiency concerns to a program that starts with traffic management may dilute the program to the point that no concern is properly addressed. I believe that NASA's research and technology development work should address specific environmental objectives along with the goal of increasing system capacity. It is not clear that this should be confined to NextGen or the JPDO.

Q5. Some of your research suggests that reduced aircraft emissions and noise can be achieved along with greater fuel efficiency by developing new types of aircraft that would operate at slower cruising speeds. Based on the apparent benefits of such new aircraft, have any manufacturers voiced interest in bringing such aircraft to the marketplace? What reaction would you expect from the flying public?

A5. Aircraft manufacturers are actively considering a range of possible options, particularly for the next generation of small, medium range aircraft that may replace the A320 and 737. To an aircraft designer the difference between Mach 0.8 and Mach 0.75 is enormous. To a passenger on a flight from San Francisco to Washington, D.C. the difference is about 15 minutes.

Most current aircraft were designed when fuel cost $0.25 to $0.75 per gallon and contributed less than 15 percent to the overall cost of a flight. With fuel costs now approaching 50 percent of total costs for some carriers, the airlines are already slowing down the existing fleet to save fuel. Re-designing aircraft with a greater emphasis on fuel efficiency, may not just help the environment, but might very well reduce the cost of flying in the future.

Questions submitted by Representative Tom Feeney

Q1. Assuming that ARMD's budget profile does not change substantially in the near-term, given a choice between continuing its current approach of fundamental research across a broad swath of research topics versus funding periodic large-scale demonstration flights at the expense of limiting research to a smaller set of projects and activities, which option would you find more attractive, and why?

A1. This should not be a black and white choice. In fact, NASA's swings in emphasis from large scale projects to more basic research and back again over the years has made it very difficult for outside researchers to be able to count on NASA support and collaboration for the kind of long-term research that NASA should be doing. Instead, like any wise investor, NASA should have a balanced portfolio, with a sustained basic research agenda, that allows the Agency to identify promising but longer-term technologies, and a small number of larger scale experiments that can allow industry to better assess when some of these ideas are worth pursuing in the private sector. This is a difficult line to walk, especially in an era of declining resources for aeronautics, but it is necessary in order that NASA's research be both forward-thinking and relevant.

Q2. During the hearing, it was suggested that ARMD research findings initially not be broadly disseminated in order to provide domestic companies an opportunity to capitalize on new discoveries. Do you agree with this concept?

a. If such a policy were implemented, what effects would it have on domestic companies' ability to do business with foreign partners and customers? Would it imperil business relationships and collaborations?

b. How does NASA's current policy compare with that of other foreign governments who underwrite aeronautics research and development? Do they publicly disseminate new discoveries?

A2. I am quite concerned that such a policy would be very difficult to implement and generally counter-productive; it would prohibit many university students from working on NASA programs, might restrict hiring by small companies of excellent researchers who were not currently U.S. citizens, and discourage collaboration among some of the top researchers in the world. Clearly, some NASA programs with direct impact on national security should restrict dissemination of results. The classification mechanism is well developed and understood by industry and academia. An intermediate form of classification is much more problematic. Currently, companies working with NASA may maintain limited data rights or government-purpose rights in cases that involve collaborative research and proprietary data. Further limiting dissemination of NASA research—especially that of a more fundamental nature, isolates NASA researchers from other experts.

Much of the work done at government-supported aeronautical research laboratories in Germany (DLR), France (ONERA), and Japan (JAXA) is broadly disseminated and, along with NASA publications, has formed an important knowledge base on which our research at Stanford is built.

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